The Blast Furnace and Steel Plant

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EASTERN MANAGER
ROBERT E. POWELL
29 West Thirty-fourth Street
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Phone—Wisconsin 5459

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The Blast Furnace and Steel Plant

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Man and Machinery

AT one of our colleges a few days ago, the Dean of Engineering, in his talk before the students, directed their attention to the enormous burden lifted from the shoulders of man by modern machinery. Tasks that in years past taxed the strength of large numbers of men are now performed by one man who has under his command forces of almost unbelievable magnitude. A lever is moved and enormous masses of metal are set in motion with a crushing strength powerful enough to reduce by several inches an ingot weighing many tons, or by a like movement, tons of iron ore are lifted, or an open hearth furnace is charged. Electricity today transmutes man power into thousands and tens of thousands of horse power.

Labor saving machinery has generally been regarded as an economic necessity rather than as a means to lighten the labor of the working man. The incentive for its adoption has not, in a majority of instances, been the outgrowth of any desire to promote humanitarianism. This latter end, although achieved, has been the indirect rather than the direct result of the movement. And, as is frequently the case, there have been opposing forces in supplanting man by machinery.

Whatever may be the rights of the contending sides, there remains the indisputable fact, that through machinery man has been elevated to a higher level, and the trend can no more be stopped than can any movement which has as its goal the betterment of working conditions.

Desulphurizing Action of Manganese*

This Paper Is a Record of the Results Obtained from Experiments Conducted to Determine the Effect of Manganese in Reducing Sulphur Content of Iron. Temperature a Controlling Factor

By C. H. HERTY, Jr.† and J. M. GAINES, Jr.‡

It is generally recognized that the presence of manganese in pig iron tends to prevent high-sulphur concentrations.§ Further, this beneficial influence is commonly credited to the formation of MnS, which, being sparingly soluble, tends to separate from the liquid iron.

This action of manganese is of considerable importance, therefore, to the maker of pig iron, whether for foundry uses or for steel-making. Of recent years, the tendency of furnace operators has been to charge a higher percentage of manganese, and it seems probable that this course has been adopted partly in recognition of the desulphurizating action of this constituent. Both in the transfer ladle and in the mixer, a lowering of the sulphur content has been noted. McCance¶ reports the following analyses taken at cast and again from the same iron on pouring from the mixer one hour later:

	At cast	One hour later
(I) Mn, per cent	1.00	0.80
S, per cent	0.070	0.038
(II) Mn, per cent	1.20	1.00
S, per cent	0.060	0.030

Wheaton** followed a month's campaign on a furnace producing high-manganese, high-sulphur iron. The iron was sampled at cast and again just before the transfer ladles were emptied into the mixer. His results were:

Manganese range	Per cent S at furnace	Per cent S at mixer
1.00–1.50 per cent (av. 1.39)......	0.087	0.041
1.50–2.00 per cent (av. 1.72)......	0.070	0.035
2.00 (av. 2.13)......	0.073	0.031

This brings out very clearly the fact that the higher the manganese the lower will be the residual sulphur.

Wheaton's findings were verified by Herty and Gaines,†† who followed the same procedure and concluded from their data that the relation of manganese to residual sulphur was one which could be expressed by the equation:

K = (per cent Mn) × (per cent residual S) = 0.070. It was added that this relation would be valid only when the iron had previously contained more than the equilibrium concentrations of manganese and sulphur, and when resulphurization by furnace slag was prevented. The temperature for these observations averaged 2400 deg. F. (1315 deg. C.).

The values for K from Wheaton's data are:

Per cent Mn	Per cent S	K
1.39	0.041	0.057
1.72	0.035	0.060
2.13	0.031	0.066

These show a fair agreement among themselves and are only silghtly below the value 0.070 reported by Herty and Gaines.

The fact that the concentrations of manganese and sulphur obeyed a relationship defined by an equilateral hyperbola

$$xy = c,$$

at once suggested the familiar law of the solubility product, as exemplified by the conduct of slightly soluble salts in water. As molten iron is a good dielectric it should be an ionizing medium, and the manganese sulphide in the melt should be dissociated into ions in equilibrium with the solid salt, which has crystalized out. It is unfortunate that in neither of the two researches quoted was a sample of the slag on the ladle obtained. On this account we do not know definitely that the ions in solution were in equilibrium with solid MnS. It is equally plausible that the MnS, after elimination, formed a slag with silica, MnO, FeO, etc., which might be present on the metal surface. If this were the case, a difference in the composition of this slag would account for the variation between the findings of Wheaton and those of Herty and Gaines.

It is evident that there are other factors besides the concentration of manganese which are influencing desulphurization. The problem is really a study of the bivariant system, Fe-Mn-S, the three phases being the vapor, the metal, and as the third either a solid or a liquid MnS slag. Therefore, at a given temperature there will be definite relations existing between the compositions of the three phases. As we are ignorant of conditions in the vapor phase, we are confined to consideration of equilibrium between slag and metal. This reasoning shows us that our factors will most certainly include the temperature and slag composition, and possibly the effect of other substances in the solutions. The present report deals only with the first-named variable, temperature. No attempt was made to control slag composition, except to carry out all determinations under as nearly identical conditions as possible. The effect of temperature is so striking that it seemed advisable to make several preliminary runs, without regard to the slag, in order to verify the influence of the former.

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*Bureau of Mines Report No. 2817.

†Physical chemist, Pittsburgh Experiment Station, Bureau of Mines.

‡Assistant physical chemist, Pittsburgh Experiment Station.

§J. E. Stead, Jour. Iron & Steel Inst., No. 2, 1892, p. 216; A. McCance, Jour. Iron & Steel Inst., No. 1, 1918, p. 243.

¶A. McCance, reference cited.

**Yearbook, Amer. Iron & Steel Inst., 1920, p. 393.

††C. H. Herty, Jr., and J. M. Gaines, Jr., Desulphurizing Action of Manganese in Iron. Trans. Amer. Inst. Min. & Met. Eng., October, 1926.

Procedure

In carrying out the determinations, an Ajax-Northrup high-frequency induction furnace of about 100 lbs. capacity was used. A charge of boiler punchings and petroleum coke was melted in a graphite crucible, with enough ferro-silicon to give samples that could easily be drilled. Ferro-manganese in the desired amount was next added and the metal surface was covered with coke to prevent oxidation. Temperatures were measured with a disappearing filament pyrometer sighted on the bottom of a closed silica tube inserted in the iron. No correction for emissivity was employed.* When the temperature reached the desired level, a predetermined quantity of iron sulphide was added. Samples were taken with the temperature falling, in order to be sure that saturation of the iron with MnS was attained.

Results

Several preliminary runs were carried out during the process of overcoming experimental difficulties, but these are not included here. The data are generally unreliable for one or more of the following reasons:

1—Failure to reach equilibrium, or saturation.

2—Uncertainty as to temperature measurements.

3—Resulphurization due to oxidation.

4—Mechanical difficulties.

Some of the first runs will be briefly referred to, as bringing out points of interest, and the last two runs, together with calculated results and conclusions, will be discussed in detail. The graphic log-sheets are shown in Figs. 1 and 2. (See also Tables I and II.)

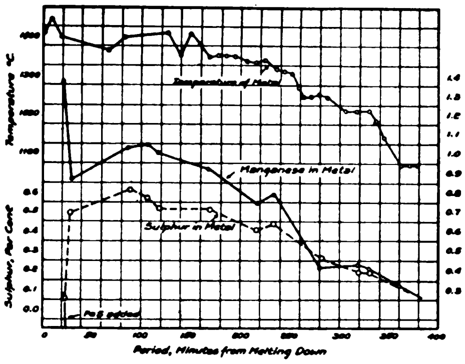

Fig. 1

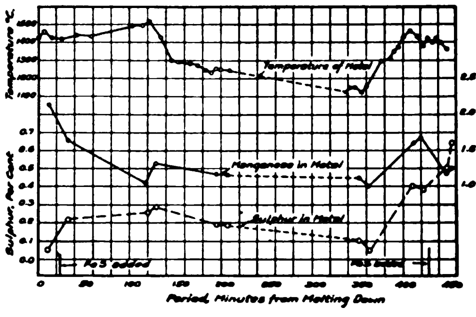

Fig. 2

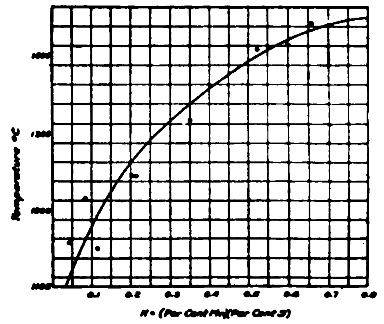

Fig. 3

In both, a sharp drop in percentage of Mn is evident on the addition of FeS, followed by an increase in percentage of Mn to its equilibrium value for that temperature. Thereafter the temperature was gradually lowered with consequent drop in the manganese and sulphur concentrations. At the end of run No. 10 (Fig. 2) the temperature was raised again, causing both the manganese and sulphur in the metal to rise. When additional FeS was added, the manganese dropped, while the sulphur increased. Run No. 9 (Fig. 1) covers the range 0.30 to 1.05 per cent Mn and run No. 10 from 1.00 to 1.75 per cent Mn. The results, calculated from the analyses, are shown in Fig. 3, where the constant K (per cent Mn × per cent S) is plotted against the temperature. (See also Table 3.) The points all fall reasonably close to a smooth curve, which shows how rapidly the quantity of dissolved MnS increases with temperature.

TABLE I—RESULTS OF RUN NO. 9

Time min.	Temperature, °C.	Sample	Per cent Mn	S	C	Si	P	K
22	1400	1	1.36	0.064	4.56	2.53	0.026	0.087
29	1400	2	0.86	0.50	4.73	2.40	.....	0.430
89	1400	3	1.04	0.62	....	....	.....	0.645
107	1400	4	1.07	0.58	....	....	.....	0.620
117	1410	5	1.01	0.52	4.36	2.47	0.027	0.525
169	1350	6	0.93	0.52	....	....	.....	0.483
219	1340	7	0.75	0.41	....	....	.....	0.307
234	1320	8	0.80	0.44	4.53	2.46	.....	0.352
292	1250	9	0.42	0.26	....	....	.....	0.109
321	1215	10	0.43	0.20	....	....	.....	0.086
332	1215	11	0.41	0.20	4.05	2.52	.....	0.082
368	1100	12	0.30	0.10	3.72	2.48	0.031	0.030

TABLE II—RESULTS OF RUN NO. 10

Time min.	Temperature, °C.	Sample	Per cent Mn	S	C	Si	P	K
11	1440	1	2.14	0.062	4.45	....	0.038	0.132
30	1425	2	1.64	0.220	4.82	1.79	.....	0.361
119	1500	3	1.06	0.253	4.43	....	.....	0.268
128	1495	4	1.34	0.286	4.50	....	.....	0.370
197	1245	5	1.17	0.182	4.66	....	.....	0.213
207	1245	6	1.15	0.179	4.31	....	.....	0.206
353	1150	7	1.14	0.100	4.09	1.74	.....	0.114
363	1160	9	1.03	0.044	3.98	1.78	.....	0.045
412	1435	9	1.62	0.410	5.64	3.14*	.....	0.665
422	1420	10	1.69	0.389	5.08	3.82*	.....	0.656
449	1415	11	1.20	0.504	4.72	3.09*	.....	0.605
456	1390	12	1.26	0.634	4.75	2.55*	0.030	0.798

*Increase in per cent Si is due to reduction of silica tube used in temperature measurements.

TABLE III—DATA COMPILED FOR FIG. 3

Run No.	Sample No.	Temperature deg. C.	K	Mn, per cent	S, per cent
9	12	1100	0.030	0.30	0.100
10	7	1150	0.114	1.14	0.100
10	8	1160	0.045	1.03	0.044
9	11	1215	0.082	0.41	0.20
10	5	1245	0.213	1.17	0.182
10	6	1245	0.206	1.15	0.179
9	8	1320	0.352	0.80	0.44
9	5	1410	0.525	1.01	0.52
10	11	1415	0.605	1.20	0.504
10	9	1440	0.656	1.62	0.389

Two other runs were made in which much higher concentrations of manganese were employed, and where a large amount of the sulphide was eliminated, yielding considerable slag (runs 7 and 8). The product K for these runs is considerably higher than for the two first mentioned, although it shows just as marked a temperature coefficient. These data are not included here for the reason that the slag formed was not sufficiently fluid to permit establishing equilibrium. Furthermore, the temperatures, taken with the optical pyrometer on the free surface of the metal, are not comparable with those in the later runs, due to uncertainty as to the degree of blackness of the object.

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*Cf. Bureau of Standards Technical Paper No. 170, p. 118.

Discussion

It will be noted from Fig. 3 that at 2400 deg. F. (1315 deg. C.) the product K is 0.30 in contrast to the value of 0.070 as found by Herty and Gaines. That this difference, as well as that for the high-manganese, high-sulphur runs mentioned above, may be due to differences in slag composition, is shown as follows:

Conditions	I Wheaton Herty and Gaines Pig-iron ladles %	II Runs 9 and 10 this paper, Induction furnace %	III Runs 7 and 8 this paper, Induction furnace %
Amount of Mns eliminated from metal (approx.).	0.03 -0.15	1.7	10-12
K at 1300 deg. C..	0.065-0.070	0.30	0.66

It will be seen that in case where large amounts of MnS are transferred to the slag, the constant is much higher. In I, we may be fairly sure that there is an appreciable amount of basic slag on the metal surface, which would tend to lower the concentration of MnS in the slag. (The disadvantages of furnace slag on the ladle will be considered later.) In II the conditions are somewhat different on account of the layer of granular coke on the metal. The result of its presence may very probably be that the sulphide upon elimination is absorbed in the porous structure of the coke and there frozen. Pieces of coke have been taken from the crucible which indicated this was the case. In III there is a slag which is quite high in MnS and is also liquid. A slag analysis for these conditions would show 29.5 per cent Mn, 2.3 per cent Fe, 16.9 per cent S, 1.5 per cent CaO, and 0.3 per cent SiO_2.

We know that at equilibrium the vapor pressures of MnS in equilibrium with slag and metal are identical; hence, if there is a difference in the amount of MnS in the metal under three different slags at the same temperature, the conclusion is valid that MnS in these slags has different pressures. Whether this pressure is a linear function of the concentration or a more complex one, depending on possible compound-formation, remains to be seen. It is reasonable to suppose, moreover, that on passing from liquid to solid MnS, one would find a break in the temperature solubility curve corresponding to the melting point of MnS.

These considerations give some idea of the complex system which must be unraveled before the mechanism of the reaction can be completely known. A continuation of the present work will extend the range of manganese concentration and will also deal with the question of slag composition.

The matter of effect of furnace slag on the ladle has been mentioned. In their work previously referred to Herty and Gaines found that if a considerable quantity of furnace slag was allowed to run into the ladle with the metal, the chances of getting any elimination of sulphur were greatly lessened. This was thought due to oxidation, and subsequent shift of the equilibrium

$$CaO + FeS \rightleftarrows CaS + FeO.$$

An increase in FeO, in the presence of slag, would tend to throw FeS back into the iron. The ease with which resulphurization may take place in the presence of an oxidizing agent was demonstrated in the course of the present investigation. Mention has been made of the fact that a layer of coke covered the metal at all times. The importance of this procedure was not realized in the earlier runs, as the following results show:

Run 1—By addition of manganese, the percentage of S had been reduced from 0.175 to 0.051. At this point the percentage of C in the metal stopped increasing, even though it was considerably below saturation. From here on there was therefore, evidently, a deficiency of coke on the metal, and the sulphur content gradually rose to 0.112 per cent.

Run 2—In order to make sure of the effect of oxidation, all coke was removed at the end of the run, causing the sulphur to increase from 0.055 to 0.080 per cent. This would probably have been higher, but for the fact that most of the slag was removed with the coke.

Inasmuch as it is practically impossible entirely to exclude furnace slag from the transfer ladle, the importance of maintaining a reducing layer above the metal surface—that is, of anthracite or coke breeze—can not be over-emphasized. Only by so doing can one expect to receive the benefits of the desulphurizing action of manganese, and to prevent even an increase of sulphur in the iron.

Certain blast-furnace operators have claimed that they preferred running the manganese fairly high, because it helped to remove sulphur in the furnace. Some open-hearth men have advanced similar beliefs, and the theory has found credence that manganese will remove sulphur from iron and steel under any and all conditions.

In the light of the data here presented, it may be said, as a first requisite for this action, that the temperature should be fairly low. If we assume that the increase of K with temperature under blast-furnace conditions is proportional to its increase under the conditions of these experiments, we have a means of approximating its value in the blast-furnace hearth. If the temperature here is assumed to be 2,650 deg. F. (1,450 deg. C.), and K at 2,400 deg. F. (1,315 deg. C.) is 0.070; and if the relative increase in K, as shown in Fig. 3 for this temperature change, is $0.775/0.30 = 2.58$; then K at 2,650 deg. F. will be $0.070 \times 2.58 = 0.181$. In other words, if the iron is running 2 per cent manganese, elimination of sulphur in the crucible of the furnace could be expected down to a point where $(2 \times \text{per cent S}) = 0.181$, or where per cent $S = 0.091$. With lower managenese in the iron, the limit on sulphur would of course be higher. This does not mean that with 2 per cent manganese the furnace cannot make better than 0.091 per cent sulphur iron, but that the manganese itself cannot be expected to eliminate sulphur below this point. Obviously, too, at open-hearth temperatures, no elimination of sulphur could be expected, on account of the tremendous increase in K, as predicted by Fig. 3.

(Continued on page 473)

The Art of Drawing Steel Wire*

Although Metal Flow Is Discussed in Some Detail, the Theme in General Is the Effect of Defective Steel on the Process of Wire Drawing. Heat Treating Considered

By E. A. ATKINS†

A PECULIARITY of wiredrawing is that the pressure which causes reduction is really due to the pull on the wire. It could not be done by pushing, as it would be almost impossible to push a hard material through a conical hole on account of the enormous resisting forces set up. In the case of a pull, however, while the pressure on the shoulder may in some cases rise to as much as 150 tons per sq. in., there is no difficulty in drawing the wire through the conical hole, due to the fact that the pull simultaneously causes intense neck pressure, bringing about a local collapse of the material, thus assisting it to pass forward. This feature of the "flow" of the steel is illustrated in Fig. 1, and its mechanism probably is very much the same as that which happens in the case either of material or of living beings getting jammed in a tapered opening, in which it will readily be seen that further pressure on the back would but tend to increase the "jam," whereas releasing by a pull from the small side of the opening would reduce the pressure and allow the "flow" to continue. By imagining the wire to be built up of an infinite number of planes at right angles to its axis, and considering what might happen to those planes as they pass through the conical hole, it may be conceived that the pull on the wire will tend to bulge forward the centre of the planes, with the result that the middle portion of the material will always be moving slightly in advance of that which is nearer to the skin of the wire. This central collapsing, therefore, may be the real secret underlying the reducing of wire through a tapered hole.

The amount by which the centre moves forward in advance of the outside, it may be supposed, will vary with the kind of material and the percentage reduction of area. With very light drafting there will be need for the centre portion to move forward perhaps only a molecule or so in advance of the outside; but with heavy drafts the forward movement of the centre will be much greater. When the drafting is heavy enough to cause a pull which is almost equal to the breaking load of the wire, it can be imagined that there will be separation of the steel at its core, the same as in the fracture of an ordinary test-piece which is on the point of breaking in the testing machine. The results of various experiments and tests give support to the theory enunciated.

Dr. Horsburgh has already demonstrated that if a fine hole be drilled at right angles to the axis of a wire and plugged with suitable material and subsequently drawn, the centre of the section moves forward slightly in advance of the two ends. While this method no doubt illustrates the relative movement of the material, it is somewhat open to question on account of the alteration of the cross-section by drilling.

Another method of showing the relative "flow" of core and surface is to square carefully the back end of a piece of wire, and after drawing to note the depth of the concavity at the end of the wire. One such test is illustrated in Fig. 2. This shows a section of a piece of 18-gauge wire, which was reduced from 10 to 18 gauge in six drafts. After each draft the cup was gradually deepened. Several other tests with different sizes of wire and different methods of drafting gave confirmatory results. It was found that when very light drafts were taken the resulting concavity was very small, but when heavier drafts were taken the cavity became deeper. This method, however, is manifestly defective, inasmuch as the material inside the cup is not supported, and, consequently, would draw out considerably more after each draft than if it were solid.

With the object of having the wire solid and at the same time being able to detect the relative "flow" of the material during drawing, several attempts were made to butt-weld different steels, subsequently sectioning them and noting the result. Two pieces of 5 gauge mild steel rod were carefully butt-welded by the electrical resistance method after the ends had been squared, as it was known that the junction would be somewhat decarburized and would give an area of material which would differ in appearance from the main portion of the rod. The rod was then drawn from 5 to 12-gauge wire in five drafts. The welded joint was then carefully sectioned, and when etched it was seen that the centre of the section low in carbon had moved in advance of the outside.

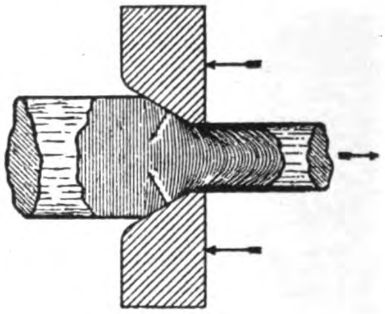
FIG. 1.

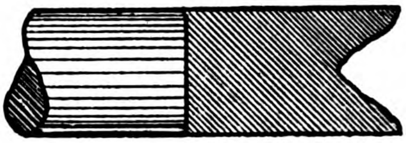
FIG. 2.

FIG. 3.

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*Mechanical World.

†Mechanical engineer.

A similar experiment was carried out by butt-welding two rods having such diverse carbon contents as 0.60 per cent and 0.50 per cent. After air-tempering, the 5-gauge rod was drawn down to 10-gauge wire in five drafts, the high carbon end of the rod passing first through the draw-plate. Careful sectioning of the resulting wire showed that there was apparently no difference between the "flow" of the core and the skin of the wire. It would appear from this experiment that in reducing hard steel by comparatively light drafts there is very little relative movement between the centre and the outside of the wire in passing through the draw-plate. This part of the investigation leads directly to the question of segregater material, which is one of the bugbears of the wiredrawer who desires to manufacture a high-class product.

Segregated Steel—It is not uncommon to find that certain portions of a cast of hard steel have segregations at the core of the rods which, unless the greatest possible care in drawing is exercised, lead to either complete or incipient fractures. Where the core is of a pronouncedly hard type the centre portion of the wire in drawing will break into cups, which may be only about ⅛ in. apart. Wire of this description is, of course, useless, and dangerous if put into service.

It may be contended that this "cuppiness" can be somewhat obviated by taking very light drafts (or reversing the wire after each draft in drawing), but the steel maker should remember that it is impossible to examine every piece of rod and subject it to a special treatment to suit its particular peculiarities. Material should be of such a quality that it will give a good quality wire when subjected to the standard practice in wiredrawing.

When steel billets are segregated, the segregation will inevitably be found in the core of the resulting wire, whatever gauge it may be drawn to, and though for some purposes there is no very serious disadvantage in the use of the wire, such material is almost useless for heading or similar work. The stresses set up by the flowing of the steel when cold-headed may be so severe as to cause the material to separate at the neck under very light pressure, or the head itself may split across its centre at right angles to the axis of the bolt. Hard wire drawn from segregated steel, it can readily be understood, is not the best quality to use for ropes.

A mild steel rod when segregated often shows a structure the outside area of which is quite diverse from the inside. In the same manner a high phosphorus material containing ghost lines will cause all sorts of trouble by splitting or breaking when worked up into wire in the cold. As is well known, the banded lines are not easily removed by any ordinary method of heat treatment—and, in any case, it is well to remember that in the treatment of ordinary material abnormal methods of manufacture cannot possibly be adopted to suit varying kinds of steel.

Surface Defects and Hollowness—Laps or spills on wire may be caused through a bad surface on ingots, due either to splashes in casting or skin blowholes. Defects may be caused during the rolling of the billets into rods by overfilling the grooves, which sets up fins. Fine cracks on billet edges due to a bad composition of steel or to overheating may cause roaks, which result in either broken wire or damaged surface. Insufficient cropping to remove "pipe" will result in producing defective rods or hollow wire, which in most cases is useless.

Effect of Non-metallic Inclusions—Slag inclusions in steel, besides causing trouble in drawing the wire to correct sizes, may also result in the necking down of the wire at the parts where the slag inclusions are segregated as groups—Fig. 3. Fortunately, this is not a very common phenomenon, but it may occasionally occur if very dirty steel is used.

The Cause of Wire "Running Out" or Not Sizing Correctly—Formerly continual disputes arose between the wire manufacturer and the steelmaker as to why some classes of steel, whether acid or basic, could not be drawn correctly to size, the wire sometimes sizing so badly that one rod of a 150-lb piece might be 17 gauge and the other end 16 gauge or larger. This meant that the wire in passing through the conical hole of the wiredrawer's plate gradually ground or pulled out the hole until it was one or more gauges larger in diameter by the time the complete piece had passed through, the resulting wire, of course, being tapered from end to end. While the wiredrawer blamed the steel, the steelmaker attributed the trouble to some defect in the wiredrawer's plate, machinery, or process in connection with the manufacture.

However, many years ago, an examination of the surfaces of evenly drawn and defective wires furnished a clue to the trouble. It was found that the one which drew even-ended had fine, unbroken drawing lines on the surface, whereas the drawing lines on the surface of the wire which "ran out" were broken up, the appearance being somewhat similar to a ploughed field in which the furrows had been trampled down by a herd of cattle. This led to a search for the cause of the breaking up of the drawing lines. Examination of the polished, unetched surfaces of the steels which drew badly indicated the presence of very minute specks of non-metallic material. When drawn into fine wire it was found that the specks were still present in the steel in their original form, thus showing that they were intensely hard and could not be elongated. After careful calculation it was found that this form of fine non-metallic speck was present in the steel sometimes to the extent of 140,000 to the square inch, or about 50 millions to the cubic inch.

Many subsequent examinations of billets, rods, and wire gave fairly accurate information as to the amount that the respective materials would "run out" in wiredrawing. Thus a mild steel, which exhibited about 40,000 specks to the square inch, increased in diameter 10 mils during the last pass when being drawn to 14 gauge, which made the wire 14 gauge at one end and 13 gauge at the other.

The Nature of the Hard Inclusions—An investigation has been carried out to discover the nature of the inclusions which cause the most trouble in drawing wire to the correct size. The first material dealt with was a hard steel with 0.65 per cent carbon. The history of its manufacture was unknown, but it ran out of size very badly when drawn into wire. Examination of a 5-gauge rod showed the specks to be of rather large size. Examination at a higher power showed that the inclusions were crystalline in form, being apparently tranparent.

A steel was chosen which was definitely "specky" in character, and was completely dissolved, and the residue collected, when examined under the microscope, was found to contain some transparent crystals in a conglomerate mass. This was subsequently treated with hydrofluoric acid, which removed the silica, but had no apparent action upon the crystals. The residue of crystals was dissolved, and subsequent analysis showed them to be composed of alumina. The great hardness of the crystals was readily shown by lightly pressing a piece of glass upon them and moving it laterally, the result being that the surface of the glass was scratched.

It can be appreciated that such hard crystals of alumina embedded in the steel have a great abrasive power in grinding the hole larger in the wiredrawer's plate. It has, of course, long been known that when aluminum is added to steel it cause trouble in "running out" in wiredrawing, but it is somewhat peculiar to find that the alumina takes the crystalline form.

It was thought that it would be of interest to add definite amounts of aluminium to particular types of steel, to examine these carefully and not the actual results in wire drawing. First of all, a basic hard steel with 0.65 per cent carbon and 0.55 per cent manganese was made, 3.7 oz. of aluminium to the ton being added as the steel was run into the ingot mold. This, when examined in the billet form, after polishing only, exhibited specks. When drawn into wire it "ran out" 7 mils while being taken down to 17 gauge.

An ingot of the same cast which had no aluminium added to the mould was shown to be practically clean when polished, only one speck appearing on a definite area. This, when drawn down to 17-gauge wire, was, for all practical purposes level ended, "running out" less than half a mil in a 160-lb. piece.

A cast of mild steel with 9.3 oz. of aluminium to the ton added to the ingot mold also showed specks. This "ran out" no less than 10 mils (more than a gauge) when drawn down from 5-gauge rod to 16-gauge wire.

Another mold of the same cast of mild steel had 19 oz. of aluminium to the ton added, the billets of this when examined showing an enormous number of specks. In attempting to draw this to wire it was found impossible to size at all, as the hole of the draw-plate was almost immediately ground out.

Samples of all the above steels were dissolved and examinations were made for the presence of the hard crystals, and in each of the "specky" materials these were discovered.

The results of the tests and examinations carried out certainly prove that where aluminium is used as a deoxidizer the resulting inclusions have the most pernicious influence in causing wire to "run out" of size through the grinding out of the hole in the draw-plate; but it should be understood that they are only one of the causes of the grinding action. Many cases of the "running out" of wire, in which it can be definitely proved that aluminium was not added to the steel during its manufacture, have been traced, and careful examinations of these casts show that the minute specks are no doubt manganese-iron silicate, and are, of course, more difficult to get rid of in the process of steel-making than the alumina specks.

Besides causing trouble in wiredrawing, the minute hard specks are no doubt one of the causes of the rapid wear of the edges of screwing and other cutting tools when steel of this character is being worked.

It is only fair to say that wire will sometimes "run out" of size for reasons quite apart from the quality of the steel. For instance, if all the scale has not been properly cleaned from the surface of the wire, if it has not been properly coated, or if the lubrication is not sufficienty good, the hole in the draw-plate may pull out. Also, if the hole in the draw-plate is not properly set, or if the material of the latter is not of the right composition or in the correct physical state. the die may not hold up, and consequently as the wire passes through, it will increase in diameter.

The Making of Clean Steel Suitable for Wiredrawing—As the quality of steel wire and several other products is very seriously affected by small non-metallic inclusions, it is worthy of prolonged investigation to discover the methods by which steels of suitable quality can be produced economically. The problem really resolves itself into one of how best to deoxidize the steel.

The removal of non-metallic inclusions in mild steel is not so difficult as in the case of medium and high-carbon steels, as the mild steel apparently lends itself better to a final prolonged treatment in the furnace with manganese, which gives time for the inclusions to float on the surface. If deoxidation has been carried sufficiently far and there are no further additions of ferro-silicon or aluminium either in the ladle or ingot molds, there would appear to be nothing, apart from refractory inclusions, which could cause the formation of specks of a non-metallic character.

In the case of high-carbon steels, if the deoxidation in the furnace has not been carried sufficiently far, the additions of ferro-manganese and ferro-silicon in the ladle will result in the formation of silicates, which will not have sufficient time to pass up out of the steel before it is run into the molds.

Dr. McCance mentions that a possible additional cause of the formation of deleterious inclusions may be the passing back of silicon from the slag into the steel, leaving myriads of silica specks which are ultimately converted into manganese silicate, or a complex silicate of manganese and iron. Possibly this may be the true explanation for the appearance of some kinds of specks.

Dissolved Oxide in Steel—Perhaps one of the most complex problems in steelmaking is that of the effect of oxide of iron when in solution in steel. This latter factor is probably one of the disturbing influences in connection with the torsioning of steel wire. The torsion test, which is commonly applied to hard steel wire, consists in twisting to destruction a definite length of the wire, say, equal to 100 diameters. Supposedly good wire will give from 30 to 40 or more twists before it fractures, and the fracture usually takes the form of a shear at right angles to the axis, but in wire of indifferent quality it assumes a ragged form.

It is difficult to know what the torsion test actually measures in wire, except perhaps that it is an indication of the density of the steel, its freedom from surface defects, and its general good quality. The torsion test results may, however, be affected in several ways. In the patenting or tempering of wire, if a high temperature is used causing large grain-size, the torsional properties of the wire are usually improved, while the other physical properties may be impaired. Again, when wire is drawn from harsh or oxidized steel, the torsional properties are very considerably reduced, and from this it would seem reasonable to conclude that the percentage amount of oxide in solution in the steel is one of the potent factors which affect the twisting of a wire. On the other hand, wire drawn from oxidized steel has considerable torsional stiffness or rigidity, which is a useful property in wire for making the cheaper kind of cylindrical or conical springs which, in practice, twist only a few degrees. It may be that there is some use for a steel or an iron which is definitely alloyed with its own oxide, and the last-mentioned case appears to be an illustration of this.

Surface Blisters After Coating—A good deal of discussion has taken place recently on the causes of blisters on coated surfaces. These blisters, as has often been proved, actually develop in the pickling cistern, and, in the opinion of the author, are due to minute inclusions which are near the surface, and which, when disintegrated, leave behind products that lift up tin or other metal during or after coating. In galvanizing, tinning, or electroplating, the occluded hydrogen may have a seriously disturbing effect upon the deposited metal.

Unfounded Complaints of Bad-Quality Steel—While the steel maker has all kinds of complaints to deal with in reference to the quality of his steel, there are many cases where complaints are unfounded. In former days material was classified as "good," "bad," or "rotten," and while perhaps the latter two qualities were reported to the steelworks, the former one was rarely mentioned. But investigation has shown that in some cases high-class material has been spoiled through wrong treatment in passing through the various processes, the quality of steel being blamed if the results were not as anticipated.

A piece of 16-gauge mild steel wire can have very varying physical properties under different conditions of heat treatment. An untreated 16-gauge mild steel wire may have a tensile strength of 64.3 tons per sq. in. and an elongation of 2.5 per cent, the wire giving 46 twists in an 8-in. length before breaking. After heat treatment the tensile strength may vary between 34 tons and 35 tons per sq. in., the elongation between 12.5 and 22.5 per cent, and the twists between 80 and 142. With such varying results of heat treatment it can readily be seen that an almost infinite variety of physical properties can be induced, even in a bit of mild steel wire, under different conditions of annealing. It is thus manifest that where heat treatment is used to bring about certain results, there is need of great caution before blaming the steelmaker for the bad quality of the steel.

Perhaps one of the most peculiar results obtained in connection with the annealing of mild steel is the extraordinary difference in the grain growth according as the area is reduced in wiredrawing. For the purpose of examining this point many wires were drawn out of identical material, and were heated in the annealing furnace in the some position and at the same time so as to ensure uniform conditions. Where three wires with respective reductions of area of 10, 20, and 30 per cent had been annealed at 690 deg. C., the number of grains to the square inch were respectively 252, 2,100, and 3,500. At a lower temperature, 590 deg. C., the wire, having a 10 per cent reduction of area, gave 4,500 grains to the square inch. Steels giving such varied results have often been denounced as worthless, whereas the problem is purely one of correct heat treatment.

Similarly, in fine wires where the annealing had not been carried out under conditions suitable to a low-carbon material, the grain was caused to flow sufficiently large to cover the full diameter of the wire, causing intense brittleness. Yet only a few inches farther along on the same wire the material was found to be tough and showed small grain.

A much more difficult case to deal with in connection with annealing is where wire has a very low carbon content near the surface and a higher content in the middle portion. This unfortunately often results in large grain growth at the surface, which, if it does not cause fracture, will produce a lumpy appearance on the surface of the wire when bent. There are also cases where the steel of wire or strip has been described as bad, but has simply been made defective by being carburized by contact with carbon monoxide, either through cracked annealing pots or through overheating in the presence of fresh cast-iron borings.

The Pennsylvania Railroad Rail Tonnage

"The 300,000 tons of steel rail to be bought by the Pennsylvania railroad in 1928 would be sufficient to lay an 800-mile double track line between Philadelphia and Chicago," remarks the New York Herald Tribune.

"Purchase of that large quantity of rail is only another evidence of the effort the carrier is making to carry out its enormous program of expansion and improvement. In 1922 the Pennsylvania purchased only 86,000 tons of rail, and in 1926, 200,000 tons were purchased. The road's expenditures for improvements are being reflected gradually in increased earnings.

"Last year the Pennsylvania spent more than $164,000,000 for fuel and materials which materially contributed to the record-breaking national prosperity of 1926. In addition, about $24,000,000 was spent for new engines and cars.

Desulphurizing Action of Manganese

(Continued from page 469)

It is entirely possible that manganese in the blast furnace and in the open hearth may facilitate sulphur elimination by rendering the slag more fluid. However, this cannot truthfully be classed as a desulphurization action of manganese.

Summary

1—The relation between the temperature and the solubility product, [K = (per cent Mn) (per cent S)] for MnS in iron in contact, presumably, with solid MnS, has been determined over the range 1,100-1,440 deg. C. and 1.00 per cent Mn to 1.75 per cent Mn. The amount of dissolved MnS increases rapidly with the temperature, the change in the product for this range being from 0.030 to approximately 0.650.

2—The composition of any liquid slag formed is pointed out as a probable factor in determining the magnitude of K.

3—The effect of oxidation on desulphurization is discussed, with examples.

4—The desulphurization action of manganese in the transfer ladle has been discussed. However, the higher temperatures prevailing within the blast furnace and in the open hearth make it probable, in view of the results here presented, that manganese cannot act in these cases directly as a desulphurizer; it may, and very probably does, assist indirectly other desulphurizing reactions.

The Duplex Process Employed in India*

Instructive Details from a Practical Standpoint Are Here Presented as They Pertain to the Manufacture of Steel by the Combined Bessemer and Open Hearth Processes

By B. YANESKE

PART II

THE examples given in Table III are taken from actual practice and show the percentage of residual silicon (and manganese) after the direct blowing of blast-furnace metal which had a high silicon content. The analysis of the metal before and after blowing is given, together with the analysis of the slag taken from the converter ladle after the blow. In each case a single or a double "kicker" was blown for finishing a charge, and, after pouring the blow metal into the open-hearth, considerable difficulty was experienced in the elimination of phosphorus from the bath; in the first two cases a rail steel was being attempted, but owing to the phosphorus not being satisfactorily eliminated by the time the carbon was right for tapping, the charge had to be worked down with iron ore and a tin bar steel made instead, with consequent loss of time.

TABLE III
Analyses of Converter Slags after Blowing High-Silicon Metal.

Analysis of blast-furnace metal Per cent			Analysis of converter metal after blow Per cent			Remarks	Analysis of converter slag after blow Per cent				
Carbon	Manganese	Silicon	Carbon	Manganese	Silicon		SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO
4.08	0.72	2.25	2.74 2.60	0.28 0.30	0.456 0.583	"Double-kicker" for rail steel; two blows in one ladle	61.47	4.07	3.85	10.11	17.82
4.13	0.84	2.06	2.78 2.99	0.32 0.29	0.608 0.547	Do.	62.20	3.28	3.57	9.88	18.52
4.05	0.68	2.16	1.33	0.21	0.442	"Single-kicker" for mild (structural) steel	60.84	3.55	4.19	10.54	18.37
4.03	0.77	1.88	1.28	0.19	0.419	Do.	59.72	3.39	4.02	11.16	19.08
4.08	0.56	2.10	1.12	0.17	0.467	"Single-kicker" for soft (tin bar) steel	60.37	4.86	3.90	10.35	17.74
3.98	0.86	1.88	1.09	0.19	0.405	Do.	59.66	4.27	3.01	10.58	19.86

The difficulty of eliminating phosphorus from the open-hearth bath was evidently due to the high percentage of residual silicon in the blown metal, together with the excessively high temperature generated in the metal during the blow by the combustion of so much silicon, the metal having been insufficiently cooled before being charged into the open-hearth furnace. It will be observed that all the slags were highly siliceous, and such slags cause the formation in the converter of "salamanders" or "kidneys," as they are called.

A low manganese content of the mixer metal produces the same effect. These "kidneys" consist of large accumulations of a very hard dark grey slag which adhere to the converter lining, and are extremely difficult to remove, while if they are allowed to collect they soon reduce considerably the capacity of the vessel. The probable cause of the formation of "salamanders" is that the slag becomes very viscous with low manganous oxide contents, particularly if the percentage of silica is high owing to a high percentage of silicon having been present in the metal. While the blown metal is being poured into the ladle and the converter is in a more or less horizontal position, the viscous slag on each side of the stream of metal in contact with the vessel lining becomes firmly attached thereto and steadily accumulates during each blow.

However, the composition of this slag becomes altered in some manner, possibly by becoming saturated with metal during pouring, for while the converter slag under such conditions is highly siliceous with a fairly low iron content, the silica content of the "salamander" is found to be considerably lower while the iron content is correspondingly higher. The following are comparative analyses of a sample of "kidney" or "salamander" slag cut from the converter lining, and the corresponding converter slag taken at the end of the blow:

	Salamander %	Converter slag %
Silica	37.76	59.47
Alumina	6.45	6.28
Ferric oxide	0.87	1.55
Ferrous oxide	33.96	12.51
Manganous oxide	14.85	14.67
Lime	1.44	1.20
Magnesia	0.33	0.27
Titanium oxide	4.01	3.79
Phosphorus pentoxide	0.062	0.055
Sulphur	0.032	0.032

Open-Hearth Tilting Furnaces to Casting House—It is the high phosphorus content of the Bessemer-blown metal which makes its subsequent refinement necessary in the basic open-hearth furnace, and to effect the elimination of phosphorus to the desired extent and at the same time obtain a sufficiently high tapping temperature, the following procedure is adopted.

After a furnace is tapped from a previous heat and rolled back into its normal position, there is approxi-

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mately 40 tons of molten steel left in the bath, for although A furnace has normally a capacity of 200 tons, and B furnace 250 tons, it has been found to be more economical to work them with maximum charges of about 150 tons, from which about 110 tons is poured at each tap.

As the average weight of each heat of blown metal from the converters is approximately 20 tons, it is necessary to charge in the open-hearth furnace five and six blows, that is, about 100 and 120 tons, alternately, in order to replace the metal tapped out and maintain the total weight of metal in the bath fairly constant and as near as possible to the 150-ton maximum charge previously mentioned. If a six-blow charge is required for the open-hearth furnace, then an extra single soft heat of blown metal is charged before the single-kicker for each grade of steel.

The usual length of time occupied between the furnace tapping and charging is 25 min., about 10 min. being taken up in pouring out the metal during tapping, and 15 min. in fettling the furnace. When the necessary repairs have been made, the gas is turned full on, and a quantity of lime (calcined limestone) and mill scale is charged, usually two or three boxes of each being added to the bath, each box containing 1000 lbs. of lime or scale, and a highly basic and oxidizing slag is thus formed.

The first two heats of Bessemer metal blown and poured into one ladle are known as a "double-soft" or "double-header," the weight of blown metal in the ladle being approximately 40 tons, and the carbon content about 0.10 per cent. This metal is conveyed to the open-hearth furnace and poured through one of the side doorways, No. 2 doorway being usually employed for the first ladle of metal.

More lime and scale are now charged, the amount depending on the grade of steel to be produced. The subsequent charges of blown metal introduced into the open-hearth bath also depend on the grade of steel, as will be observed from the particulars of various charges given below.

If a soft or mild steel (tin bar or structural grade) is required, then either two or three more single soft blows (0.10 per cent carbon), depending on the weight of the metal in the open-hearth bath, are poured into the furnace, each of these charges weighing about 20 tons. The second charge of soft blown metal is usually poured into the furnace through No. 4 doorway, and subsequent soft blows through No. 2 and No. 4 doorways alternately. The metal is distributed in this manner in order to prevent the undue wearing of any one breast.

After each charge of this low-carbon Bessemer metal more lime is charged, accompanied by scale at first until an average of about 7000 lbs. of the latter has been used. Lime is then added by itself according to the requirements of the furnace bath, as indicated by the appearance of the slag, the average amount used being about 13,000 lbs. for tin bar steel (0.030 to 0.070 per cent phosphorus) and 16,000 lbs. for structural steel (0.050 per cent maximum phosphorus). Occasionally, instead of two single soft blows being charged into the furnace after the first "double-header," a second "double-header" is charged, the two heats being blown and poured into one ladle in order to save a journey of the ladle crane, but single blows are preferred after the first "double-header," as lime can be more rapidly worked into the slag between the single blows.

The final charge of blown metal is known as the "single-kicker," and consists of 20 tons of metal containing about 1 per cent carbon for soft steels, and from 1¼ to 1¾ per cent carbon for mild steels, depending on the carbon required in the finished steel.

As only one converter can be blown at a time with the present blowing-house equipment, the normal length of time occupied between each charge of Bessemer metal is from 15 to 20 min., so that five blows totaling 100 tons are charged in ¾ to 1 hr., and six blows totaling 120 tons in 1 hr. to 1 hr. 20 min.

Immediately the final blow of carbon-bearing metal is introduced into the open-hearth bath, the highly oxidizing conditions which prevail cause the very rapid elimination of carbon, thus: $FeO + C = Fe + CO$. This carbon monoxide gas, passing up through the metal and slag, causes violent agitation of the bath, so that a most vigorous "boil" is produced. The center doorway is always employed for the introduction of a high-carbon blow or "kicker," and as soon as this "kicker" is completely poured into the furnace the reaction becomes extremely vigorous, and the slag as a result increases in volume by its admixture with the evolved gas bubbles passing through it, and pour (or is "kicked") out of the furnace side doorways Nos. 2 and 4, the doors of which have been previously raised to allow the slag to flow out during the "kick" into the slag hole at the charging side of the furnace, whence it is subsequently removed to the slag dump.

While the charge is thus vigorously boiled in the presence of a highly basic oxidizing slag, the phosphorus in the metal is rapidly oxidized to anhydrous phosphoric acid, P_2O_5, which combines with the lime present to form calcium phosphate, $Ca_4P_2O_9$, and the slag which overflows through Nos. 2 and 4 doorways contains a considerable amount of this P_2O_5. The vigorous boiling continues for a few minutes until almost all the carbon is removed, when the violence of the reaction diminishes, until finally the metal becomes quiet. When this stage is reached a sample of metal is taken from the bath in a spoon and poured into a small rectangular cast-iron mold, the inside dimensions of which are 6 in. x 2 in. at the top and 5½ in. x 1½ in. at the bottom, the mold being 2 in. deep. The sample is allowed to solidify, and is then quenched in water until cold, and broken for an examination of the fracture, from the appearance of which the condition of the metal in the bath is judged, and further steps taken as indicated by the sample.

If the carbon after the boil is judged to be sufficiently low, a similar sample, or half the fractured sample, is drilled for analysis, the carbon, manganese, and phosphorus being determined. If the carbon in the bath is higher than required after the "kick" and the bath is sufficiently hot, iron ore is added until the fracture of a sample indicates that the desired carbon is reached. For soft steels, such as for sheet bar and tin bar, the bath is allowed to boil until the carbon is not above 0.08 per cent, iron ore or scale being added if necessary to speed up the oxidation. For mild steels, such as structural steel, to finish with 0.22 to 0.26 per cent carbon, it is desirable to catch the carbon at about 0.18 per cent.

Before tapping a mild steel heat (specification 0.50 per cent maximum phosphorus) it is desirable that the phosphorus content of the metal should not exceed 0.028 per cent to allow sufficiently for rephosphorization, which frequently occurs, owing to the return of

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some phosphorus from the slag to the metal in the finishing stages, and also on account of the addition of phosphorus in the ferro-manganese. For tin bar heats (specification 0.030 to 0.070 per cent phosphorus) the phosphorus in the bath may be as high as 0.045 per cent before tapping. If, however, the analysis shows that there is too great a quantity of phosphorus remaining in the metal after the "kick," it is necessary to work the charge down until the carbon is not above 0.08 per cent. More lime is added, followed by a box of basic pig iron (3500 lbs.) to cause a further reaction. Sometimes when the phosphorus after the "kick" is much higher than anticipated another "kicker" of, say, 10 to 20 tons is added instead of pig iron, provided there is room in the furnace bath for the extra blow. In this case one soft blow less is charged for the next heat.

As soon as the bath has assumed its proper composition, the metal is tested for heat by rabbling the bath with a 1¼ in. square steel rod. If the metal is judged to be sufficiently hot, which is indicated by a clean-out rod with no signs of adhering metal, a box of ferro-manganese (1800 lbs.) is added to the bath for a mild (structural) steel heat and the furnace tapped eight minutes later. For soft steels, such as for sheet and tin bar, no ferro-manganese is added to the bath.

Should the temperature of the bath towards the end of the process be too low, as indicated by the appearance of the steel bar after immersing it in the metal for about one minute, a similar procedure is followed as when high phosphorus is encountered; a box of pig iron (3500 lbs.) is added to the bath to cause a reaction as soon as almost all the carbon has been oxidized from the metal, to enable the bath to acquire more heat during the boil. This is repeated if necessary, but if the bath is very cold a heat of high-carbon blown metal of 10 to 20 tons weight and containing 1.50 to 2 per cent carbon is charged into the furnace instead of cold pig iron, always provided there is sufficient room in the furnace bath for this extra blow.

Directly the furnace is ready for tapping, the tap-hole is opened by clearing out the lime with which it was closed; it is at once plugged with about four rolls of wet sacking, in order to ensure the tapping of the metal before the slag, for it is very important that the latter be held back until the end of the tap, otherwise a very heavy loss of manganese would result. Furthermore, a big jump in phosphorus might occur, and it would also be impossible to recarburize the metal satisfactorily. The furnace is then tilted for pouring. Before the sacking is burned through, the slag is high up the tapping side wall well above the tap-hole, so that clean metal comes from the furnace first. The alloys are then added to the ladle, and also coke dust for recarburizing when necessary.

For mild steels, 1800 lbs. of low-phosphorus ferro-manganese (averaging 73.5 per cent manganese) is added to the furnace bath as previously mentioned, and the remainder, the weight of which depends on the manganese content of the metal in the bath, is added to the ladle together with 180 lbs. of ferro-silicon (75 to 80 per cent silicon), and coke dust if required. For mild steels, the manganese specification for which is 0.50 to 0.70 per cent, the amount of low-phosphorus ferro-manganese required in the ladle, in addition to that added to the furnace bath, is 1400 lbs. with 0.10 per cent manganese in the bath.

For tin and sheet bar steel, the manganese specification for which is 0.40 to 0.60 per cent, all the ferro-manganese is added to the ladle, 2240 lbs. of low-phosphorus ferro-manganese or 2495 lbs. of high-phosphorus ferro-manganese (averaging 66 per cent manganese) being required, with 0.10 per cent manganese in the bath. If the bath is very low in phosphorus the high-phosphorus alloy is used, whereas if the phosphorus in the bath is sufficiently high, then the low-phosphorus alloy is employed. For these low-carbon steels 360 lbs. of ferro-silicon is added in the ladle.

The metal from the furnace is poured until the ladle is filled within approximately 4 in. of the top, when the furnace is rolled back until sufficient slag is tapped to just cover the surface of the metal, following which the furnace is rolled into its normal position after tilting it a little towards the charging side to drain out the tap-hole.

The normal time occupied in making a tin bar heat of five blows is 1 hr. 50 min., and for a six-blow charge 2 hr. 10 min.; while for a mild (structural) steel heat of five or six blows, 2 hr. and 2 hr. 20 min. respectively are occupied from commencing to charge to tapping the furnace. As previously stated, the normal time between tapping and recharging is 25 min. Soft and mild heats are frequently made in much less time in very favorable circumstances, for on several occasions tin bar heats have been made in 1 hr. 20 min. and mild steel heats in 1 hr. 40 min., the record time for a five-blow heat for tin bar steel being 1 hr. 5 min. (cast 6555B, made on November 16, 1926); while, on the other hand, difficulty in eliminating phosphorus to the desired extent, lack of heat in the furnace bath, converter delays, breakdown of equipment, etc., will, of course, cause the above normal times to be exceeded. Tin bar steel is occasionally made without a "kicker" at all, for it sometimes happens that after the four or five soft blows have been charged into the open-hearth, a delay occurs at the converters before the "kicker" can be blown. In such cases, if the delay is likely to be of too long a duration, a reaction is caused in the furnace bath by the addition of a box of pig iron (3500 lbs.), and, provided the phosphorus is sufficiently low and the metal hot enough, the furnace is tapped and an extra blow charged for the next heat.

If a rail heat is being made, the specification for which is carbon 0.55 to 0.65, manganese 0.65 to 0.85, phosphorus and sulphur 0.050 per cent maximum, then a different procedure is adopted and, as far as the author is aware, the method followed at the duplex plant of the Tata Company for making rail steel is the only one of its kind in the world. After the first charge of about 40 tons of soft blown metal carrying about 0.10 per cent carbon, preceded by the addition of about 3000 lbs. each of lime and scale, a further soft blow is charged only in the event of a six-blow charge of about 120 tons being required to fill the furnace. If only a five-blow charge of about 100 tons is required, then lime and scale together are added to the bath until a total of about 7000 lbs. of the latter has been charged, after which lime is added alone. When following one rail heat with another, it is sometimes necessary to add some iron ore to the furnace bath in order to speed up the oxidation of the carbon when the soft blows do not sufficiently dilute the percentage of carbon left in the bath from the previous rail heat, for it is essential that the carbon in the bath be not more than 0.10 per cent before a "kicker" is charged.

When the lime is almost completely worked into the slag and the carbon in the bath is sufficiently low, a "single-kicker" of about 20 tons of metal partially blown to contain about 1 per cent carbon is ordered from the Bessemer department. This blow is usually charged into the furnace about 1¼ hr. after the last soft blow, during which time a further addition of about 4000 lbs. of scale and 10,000 lbs. of lime have been made to the bath. The single "kicker" is poured into the furnace through the middle doorway (No. 3), and the violent reaction which ensues causes the ejection of slag through Nos. 2 and 4 doorways. About 6000 lbs. more lime is added, and after the reaction has subsided samples of metal are taken and fractured for examination, and one sample is sent to the laboratory to be drilled for a phosphorus determination. The bath is allowed to boil down until only 0.05 to 0.10 per cent carbon remains in the metal before the final blows are charged, the elimination of this element being speeded-up by the addition of iron ore if necessary. It is absolutely essential when making rail steel that the phosphorus in the metal be not more than 0.028 per cent before the final "kicker" is added, and if the analysis shows that the phosphorus content is more than this, a box of pig iron (3500 lbs.) is added together with more lime in order to cause a further reaction in the bath and effect the elimination of more phosphorus. This procedure is repeated if necessary.

Directly the percentages of phosphorus and carbon in the metal are sufficiently low, the final blows are ordered from the Bessemer department. These consist of two heats of partially blown metal, which are poured into one ladle and are known as a "double-kicker," the blow stopped and the vessel turned down when the steel blower judges the carbon in the metal to be from 2.50 to 2.75 per cent. Each heat is of about 20 tons weight, so that the weight of metal poured into the furnace is about 40 tons.

As it is much more difficult to ensure the elimination of sufficient phosphorus, and as its reduction from the slag is more likely when there is much carbon present in the bath, the average amount of lime used for rail steel heats is greater than for soft or mild steels, being about 19,000 lbs., all of which is usually added before the "double-kicker" is poured into the furnace. The usual time occupied between the single and double "kicker" is about 1¼ hr. The introduction of the very high-carbon "double-kicker" into the very low-carbon bath through the middle doorway (No. 3) again causes the vigorous ejection of slag through Nos. 2 and 4 doorways, the reaction this time being much more violent than that obtained after the "single-kicker." This violent reaction continues for a few minutes, after which the bath gradually quiets down. Samples are then taken, quenched and broken for inspection, and directly it is seen that the bath has settled down to a steady boil, which it usually does in about 20 to 25 min. after the "double-kicker" is charged, a sample is taken and drilled for the determination of carbon, manganese, and phosphorus.

Before the addition of the "double-kicker," the bath contained about 110 tons of metal with 0.05 to 0.10 per cent carbon, and the addition of the 40-ton "double-kicker" containing about 2.50 to 2.75 per cent carbon theoretically increases the carbon in the furnace bath to 0.75 per cent, but under normal conditions the result of the first carbon determination is usually about 0.65 per cent, with about 0.025 per cent phosphorus and 0.10 to 0.15 per cent manganese.

Samples are periodically drawn from the furnace bath and are quenched and fractured for examination, one-half being drilled for a carbon determination, while every alternate sample is analyzed for phosphorus and manganese. Any noticeable increase in the manganese content is viewed with suspicion, for if this element is being reduced from the slag to the metal it is an infallible sign that the slag is in an unsatisfactory condition, and that, although the phosphorus content as shown by analysis may be sufficiently low when the carbon is right for tapping, there will be a big jump in the percentage of phosphorus, either before tapping the furnace (the rise of phosphorus occurring usually after the addition of ferro-manganese to the bath) or during tapping. In the event of a steady rise of manganese occurring, the manufacture of a rail steel is not attempted, but iron ore is added and a mild or soft steel made instead, as it is much easier to eliminate the phosphorus with a low-carbon content of the metal.

Besides the ordinary oblong sample which is fractured another kind of sample is taken for rail heats, the metal being poured from a spoon into a circular mold about 1½ in. in diameter by 12 in. long, made in two halves; from the manner in which the steel behaves as it solidifies in the mold, the carbon can be very accurately judged, especially between 0.60 and 0.40 per cent. After solidifying, about 4 in. of the bottom part of this round sample is cut off with a sett, flattened down with a hammer, quenched in water, and drilled for analysis.

For rail steel, it is desirable to catch the carbon during the boil at about 0.54 per cent, and as soon as the analysis of the metal shows that this carbon is being approached and the percentage of phosphorus in the bath is sufficiently low (that is, below 0.028 per cent, above which a rail steel is not attempted), and the manganese content has not increased to any serious extent, a final sample is sent for carbon determination and a box of low-phosphorus ferro-manganese (1800 lbs.) is added to the furnace bath. The metal is, of course, periodically tested for heat by rabbling the bath with a steel bar, as previously stated.

Fifteen minutes after the addition of ferro-manganese the furnace is tapped as before described. In the meantime the final carbon result is obtained, which is rapidly determined by the volumetric combustion method, and if the carbon is below 0.54 per cent the deficiency is made up by the addition of 40 lbs. of coke dust for each 0.01 per cent required. The remainder of the ferro-manganese required is added to the ladle, 1680 lbs. being added when the manganese in the furnace bath is 0.10 per cent, and 80 lbs. of ferro-silicon (75 to 80 per cent silicon) is also added in the ladle.

The normal time elapsing between the addition of the "double-kicker" and tapping the furnace is about 1½ hr.; the total time taken for a normal five-blow charge for rail steel is about 4 hr., and for a six-blow charge about 4¼ hr. from the commencement of charging to tapping. The record time for a five-blow rail heat is 2¾ hr., which has been accomplished on several occasions. Tin bar and mild steel are usually made in one furnace during alternate weeks and the mill rolls changed accordingly, while the other furnace mostly makes rail steel.

To make the duplex process clearer, particulars of an actual charge are given in Table IV.

Occasional departures from normal practice occur owing to various circumstances. On Saturdays the top tap-hole (there are two tap-holes) is cut down before the last heat for the week is tapped, and only a four-blow heat of 80 tons is charged, consisting of two soft blows in one ladle, one single soft blow, and a "single-kicker" running about 0.80 to 1 per cent carbon, so that after the last heat is tapped not more than 20 tons of metal is left in the furnace during the week-end. Only tin bar steel is made with this last heat, which is usually tapped 1½ hr. after commencing to charge, as the cutting down of the tap-hole frequently causes the slag to enter the ladle with the metal during tapping, usually resulting in a considerable rise of the phosphorus content of the steel owing to a reaction between the metal and the slag in the ladle. Satisfactory recarburization with coke dust is, of course, impossible in these circumstances, so that, unless the phosphorus in the metal is very low and the carbon is caught at the right percentage, the production of a medium or higher carbon steel is impracticable.

Whenever the sulphur content of the mixer metal is running high, say over 0.050 per cent, owing to a high percentage of this element in the pig iron from the blast-furnaces, it is the practice to charge about 1000 lbs. of manganese ore into the open-hearth furnaces early in each heat.

Unlike the usual American practice, the duplex open-hearth furnaces of the Tata Company are not drained out each week-end, and it is not until a furnace is to be shut down for a long repair necessitating the cooling down of the furnace, or the bottom requires repairing as indicated by a boiling up of the metal, that the furnace bottom is ever drained. A furnace can be worked for many weeks without the necessity of seeing the bottom, as the wearing of the latter is so very slight.

It is absolutely essential that as little acid slag as possible from the converter be allowed to enter the basic open-hearth furnace, on account of the fact that the phosphate content of the slag and the phosphorus content of the metal may be increased or diminished simply by changes in the concentration of silica. It is also found that as the silica decreases the ferrous oxide increases, so that a low percentage of silica means more complete dephosphorization. Further, the less silica the slag contains the more phosphorus it is able to retain.

The weight of basic slag produced during the open-hearth process amounts to about 11¾ per cent of the weight of steel ingots. With regard to the final composition of the slag, average analyses of normal slag samples taken from the furnace bath immediately prior to the furnace being tapped are given in Table V.

The average open-hearth losses amount to approximately 6½ per cent of the metallic charge, which includes blown metal from the converters, additions such as pig iron, ferro-alloys, and the metallic contents of the mill scale and iron ore and of any manganese ore charged. These additions average 4½ per cent on the weight of blown metal charged, therefore the loss on the actual weight of blown metal poured into the furnace calculated from the weight of steel

—Particulars of Duplex Charge for Structural Steel (*Cast* 6635*B*).

Grade of Steel.	Time Last Heat Tapped.		Time from Tapping to Recharging.		Time commenced Charging Hot Metal.		Time finished Charging Hot Metal.		Time Furnace Tapped.		Duration of Heat in Furnace.		Time Ladle Filled.		Time commenced Casting.		Time finished Casting.		Diameter of Nozzle.
	Hr.	Min.	Hr.	Min.	Hr.	Min.	Hr.	Min.	Hr.	Min.	Hr.	Min.	Hr.	Min.	Hr.	Min.	Hr.	Min.	
Structural	15	35	0	40	16	15	17	00	18	05	1	50	18	13	18	15	18	38	1⅜ in.

Hot Metal Consumed.

Analysis of Mixer Metal.					Weight of Mixer Metal charged into Converter.	Carbon required in Blown Metal.	Period of Blow.				Duration of Blow.	Blast Pressure.	Carbon in Blown Metal from Analysis.	Time Blown Metal charged into O.-H. Furnace.		Weight of Blown Metal charged into O.-H. Furnace.	No. of Doorway Metal Poured through.
							Commenced.		Finished.								
C.	Mn.	S.	P.	Si.													
%	%	%	%	%	Lbs.	%	Hr.	Min.	Hr.	Min.	Minutes.	Lbs. per sq. in.	%	Hr.	Min.	Lbs.	
4·05	0·64	0·041	0·357	0·90	53,200	0·10	15	22	15	37	15	23	0·06	16	15	96,320	4
,,	,,	,,	,,	,,	52,640	0·10	15	46	16	01	15	19	0·07				
,,	,,	,,	,,	,,	60,480	0·10	16	05	16	19	14	20	0·07	16	30	54,880	2
,,	,,	,,	,,	,,	58,800	0·10	16	22	16	35	13	20	0·08	16	45	53,760	4
,,	,,	,,	,,	,,	55,440	1·50/1·75	16	38	16	50	12	19	1·76	17	00	50,400	3
Total . . .					280,560								Total . . .			255,360	

Lime Consumed.			Mill Scale Consumed.			Finishing Additions.				Ingots Produced.		Weight of Skull in Ladle.
Time.		Weight.	Time.		Weight.	Time.		Alloy, &c.	Weight.	Number.	Weight.	
Hr.	Min.	Lbs.	Hr.	Min.	Lbs.	Hr.	Min.		Lbs.		Lbs.	Lbs.
15	50	2,000	15	50	3,000	17	57	Ferro-manganese (low phosphorus)	1,800	28	251,160	2,400
16	00	2,000	16	00	2,000	In ladle		Do.	840			
16	15	2,000	16	15	2,000	In ladle		Ferro-silicon	180			
16	50	2,000				In moulds		Aluminium	27			
17	00	2,000										
17	20	1,000										
17	30	1,000										
17	45	1,000										
18	00	1,000										

Analyses of O.-H. Bath Samples.							Specification for Steel.					Actual Analyses of Ladle Samples.					
Time Taken.		C.	Mn.	S.	P.	Si.	C.	Mn.	S.	P.	Si.	No. of Sample.	C.	Mn.	S.	P.	Si.
Hr.	Min.	%	%	%	%	%	%	%	%	%	%		%	%	%	%	%
17	20	0·24	0·14	...	0·035	...	0·22 to 0·26	0·50 to 0·70	Maximum 0·050	Maximum 0·050	...	1	0·22	...	...	...	...
17	40	...	0·14	...	0·040	...						2	0·22	0·58	0·032	0·037	0·043
17	50	0·18	0·13	...	0·025	...						3	0·21	...	...	...	...
17	55	...	...	...	0·025	...											

TABLE IV

poured out of the furnace into the ladle amounts to only about 2 per cent on account of the above metallic additions. The average yield of steel poured into the casting ladle from the open-hearth furnace is, therefore, about 88 per cent of the original weight of blast-furnace metal.

With reference to the life of the furnace structure, the maximum number of heats obtained with a furnace roof was 686 heats on B furnace. In this case the whole roof was constructed of a series of panels and ribs, the panels consisting of four rings of 12 in. silica bricks, and the ribs of two rings of 16 in. silica bricks. During this run only one minor repair was executed, a small patch being required near the center of the roof after 611 heats. The next roof on B furnace lasted 768 heats, but after 364 heats the center portion measuring about 20 ft. in length was renewed.

TABLE V

Average Composition of Duplex Basic Open-Hearth Finishing Slags.

	Grade of Steel		
Constituent	Tin Bar	Mild (Structural)	Rail
	Per Cent	Per Cent	Per Cent
Silica	14.37	14.81	15.64
Alumina	2.48	2.04	1.47
Ferric oxide	2.43	2.76	4.29
Ferrous oxide	18.67	13.50	10.26
Manganous oxide	5.05	7.44	6.98
Lime	44.12	46.40	48.45
Magnesia	5.92	5.36	4.87
Titanium oxide	0.66	0.70	0.63
Phosphorus pentoxide	6.18	6.92	7.43
Sulphur	0.068	0.096	0.112

At present both A and B furnace roofs are constructed with the center portion consisting of panels and ribs as above described, and the end portions of bonded brickwork for which 12 in. silica bricks were employed, with a joint 1½ in. wide left between the center section and the end bonded sections, and a further allowance of 4 in. for expansion at each end of the roof between the brickwork and the water-cooled chills.

The port blocks were run for 768 heats without repairs, while the checker bricks were run for both the roofs referred to, that is, for 1454 heats. While the former roof was being renewed as much dust as possible was removed from the checker bricks by blowing with steam jets, while after 1454 heats all the bricks were taken out and the regenerator chambers thoroughly cleaned, after which the majority of the firebricks were again used for checkering. The average life of the furnace charging side walls is 312 heats.

"Rimming" or "effervescing" steel is occasionally made for sheet bar and tin bar, and at the present time comparisons are being made of the yield of finished rolled material made from this steel and from the ordinary almost "killed" steel, but so far, the latter has been found to give much the better yield. "Rimming" steel is, however, a little cheaper to make, as no silicon is added to the furnace or the ladle and much less aluminum is required in the mold, but whereas no piping occurs in the ingots, considerably more segregation takes place.

When making rimming steel there is no difference in the working of the furnace from the method described for ordinary steels, except that care is taken to obtain a highly oxidizing and mobile slag just prior to tapping, and whereas it is not necessary to greatly over-oxidize the steel, it must contain a sufficient amount of carbon monoxide to produce the "rimming-in" effect in the molds. It is essential that silicon be eliminated to a very high degree, as this element in the bath protects the carbon from oxidation and thus diminishes the vigor of the boil, and therefore limits the amount of carbon monoxide formed. On this account no silicon whatever is added either in the furnace or in the ladle. The amount of aluminum added in the molds while casting depends on the behavior of the steel in the first mold during the evolution of the gas. Effervescence may be either too strong or too weak. Too vigorous effervescence is caused by over-oxidation of the steel, as the result of too great an excess of oxide of iron in the furnace bath when the furnace was tapped. In this case the steel settles excessively in the molds as it freezes, sometimes to almost half its former volume. This settling of the steel can be counteracted by suitable aluminum additions, and the addition of the correct amount of this deoxidizer, probably 3 oz. per ton of steel, will cause the steel to "rim in" level. Too weak effervescence is caused by there being insufficient oxide of iron in the bath before tapping the furnace, or the steel may have been tapped at too high a temperature. The result, in this case, is that the steel rises considerably after casting and may flow over the tops of the molds. If the steel begins to rise without any additions of aluminum, slow teeming is the only means of checking it. When the evolution of gas is right the steel during effervescence tends to settle about 2 in. or 3 in. in the first mold, and the addition of a little aluminum, usually about 1 oz. per ton of steel, is required in the other molds to cause the ingots to "rim in" horizontally and have flat tops, which is the desired object.

It frequently occurs that although the major portion of the steel has "rimmed in" horizontally, the last steel to solidify in the center of the ingot has a tendency to rise considerably on account of gas still remaining in the steel being evolved at an increased pressure, due to the increased resistance caused by the diminished area of liquid steel left for its evolution at the top of the ingot. In such cases it is the custom to place a flat steel or cast-iron plate about 18 in. square and 1 in. thick on the top of the ingot as soon as this tendency to rise is observed, in order to check it.

When the steel is excessively hot in the mold there is no effervescence, and the steel continues to rise after teeming. Such ingots will consequently have spongy tops unless an excessive amount of aluminum is added to thoroughly deoxidize the steel, in which case the ingots will be badly "piped." The most satisfactory rimming steel is made when the casting temperature of the steel is such that a bottom skull is left in the ladle after casting.

The average loss of steel in the casting house—that is, the difference between the weights of the steel poured from the furnace into the ladle and of the steel ingots despatched to the mills—is approximately 2½ per cent. The average weight of ladle skulls is about 2400 lbs.

The average yield, therefore, from blast-furnace metal (including subsequent additions during its conversion) to steel ingots works out at a little over 85½ per cent.

Patents Covering Pipes and Tubes

As There Has Been Much Activity in the Manufacture of Tubular Products, This List Was Compiled with the Hope that It May Be Helpful to Those Investigating the Subject

By E. H. McCLELLAND*

THIS list of United States and British patents supplements the list of references on seamless steel tubing published in the Blast Furnace and Steel Plant in February, March, and April, 1927. German patents may be approached through the following publication: "Nummernliste der Deutschen Patentschriften nach rund 8,000 Gruppen. Sachlich geordnet; bearbeitet im Kaiserlichen Patentamt." Ed. 2. 1912. This is arranged according to classes, subclasses, and groups of the German patent classification, giving the numbers of all patents in each group. Patents on seamless steel tubing are listed in Class 7 (subclass 7a, groups 13, 14, and 18; and subclass 7b, groups 8, 9, and 10).

United States Patents

In the United States Patent Office classification, Class 78 (subclass 9) and Class 80 (subclass 4, 11, and 62) contain patents on seamless steel tubing. The *Carnegie Library of Pittsburgh* has a list of patent numbers in each of the above classes, brought up to May 31, 1921.

Aiken, Andrew J., Jr. Apparatus for Producing Seamless Tubes. (1,497,467.)

Allderdice, Winslow. Pipe-Mandrel. (757,872.)

Altman, Moise. Apparatus for Making Seamless Tubes. (961,394.)

Appleton, William H. Machine for Rolling Seamless Tubes. (369,311.)

Appleton, William H. Machine for Rolling Seamless Tubing. (412,010.)

Appleton, William H. Machine for Rolling Seamless Tubing. (412,011.)

Appleton, William H. Machine for Rolling Seamless Tubing. (412,012.)

Appleton, William H. Rolling-Mill. (394,635.)

Astfalck, Wiland. Press for Forming Tubes, Etc. (847,635.)

Baker, James H. Punching and Forging Apparatus. (671,430.)

Beck, Arthur E., and *Townsend, George.* Apparatus for the Production of Tubes. (770,997.)

Becker, Theodor. Process and Device for Producing Hollow Blocks for Manufacturing Seamless Tubes. (1,455,703.)

Blaxter, George H. Automatic Adjusting Mechanism for Reelers for Tubes, etc. (1,059,821.)

Blaxter, George H. Automatic Adjustment for Reelers. (1,040,862.)

Blaxter, George H. Manufacture of Seamless Tubing. (876,856.)

Blaxter, George H. Method of Making Seamless Tubes. (1,076,545.)

Blaxter, George H. Method of Reeling Tubes. (1,059,955.)

Blaxter, George H. Swaging-Mill. Reissue, (13,377.)

Brace, Porter H. Process of Making Seamless Tubing. (1,396,918.)

Briede, Otto. Manufacture of Tubes. (914,332.)

Briede, Otto. Manufacture of Tubes, (914,333.)

Briede, Otto. Method of Manufacturing Seamless Tubes. (974,744.)

Brock, Richard E. Method of Rolling Tubing. (1,040,134.)

Brock, Richard E., and *Selkirk, William M.* Tube-Rolling Apparatus. (1,020,399.)

Brock, Richard E., and *Selkirk, William M.* Tube-Rolling Apparatus. (1,046,436.)

Brooks, William F. Cores for Tubing. (163,148.)

Brooks, William F. Manufacture of Metal Tubing. (146,868.)

Brown, William H. Art of Making Seamless Tubes. (377,349.)

Brown, William H. Art of Making Seamless Tubes. (377,348.)

Brown, William H. Process of Making Seamless Tubes. (316,600.)

Burdon, Levi L. Manufacture of Solder-Lined Seamless Tubes. (525,676.)

Burton, James Henry. Improvement in the Manufacture of Gun-Barrels. (Reissue, 4,686.)

Capron, Marshall F. Mechanism for the Manufacture of Seamless Tubes. (843,867.)

Capron, Marshall F. Mechanism for the Manufacture of Seamless Tubes. (843,868.)

Capewell, George J. Apparatus for Perforating Billets or Ingots. (575,104.)

Ciangherotti, Corrado. Apparatus for Manufacturing Weldless Metal Tubes. (689,668.)

Clark, Edred W. Machine for Forming Seamless Tubes. (454,030.)

Crane, Newton. Process and Apparatus for Making Seamless Tubing. (1,444,953.)

Davis, Leonard D. Manufacture of Seamless Tubes. (1,123,178.)

Davis, Leonard D. Mechanism for Piercing or Shaping Metallic Ingots. (829,100.)

Davis, Leonard D. Process of Producing Seamless Internally-Ribbed Tubes. (1,465,073.)

Davis, Leonard D. Swaging-Mill. (771,611.)

Dicks, William, and *Blaxter, George H.* Guiding Device for Tube-Mills. (693,381.)

Diescher, Samuel Endres. Apparatus for Manufacturing Seamless Tubing. (667,686.)

Diescher, Samuel Endres. Manufacture of Billets for Seamless Tubes. (1,529,301.)

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*Technology Librarian, Carnegie Library of Pittsburgh.

Diescher, Samuel Endres. Manufacture of Seamless Tubes. (1,056,326.)

Diescher, Samuel Endres. Manufacture of Seamless Tubes. (1,067,806.)

Diescher, Samuel Endres. Manufacture of Seamless Tubes. (1,139,957.)

Diescher, Samuel Endres. Manufacture of Seamless Tubes. (1,280,683.)

Diescher, Samuel Endres. Tube-Machine. (650,894.)

Dunn, Jerry J. Method of Making Steel or Alloy Tubes. (1,006,186.)

Earl, Luther D. Tool for Piercing Billets. (1,374,369.)

Ehrhardt, Heinrich. Apparatus for Producing Tubular Bodies. (724,270.)

Ehrhardt, Heinrich. Process of and Apparatus for Manufacturing Tubular Bodies. (495,245.)

Fassl, Aloys. Method of Rolling Tubes. (988,634.)

Fassl, Aloys. Method of Rolling Tubes. (Reissue, 13,500.)

Fassl, Aloys. Rolling-Mill for Rolling Out Hollow Blocks. (988,868.)

Findlay, John. Machine for Making Seamless Tapered Tubes. (557,791.)

Forster, Hermann, von. Manufacture of Cold-Drawn Seamless Tubes. (1,205,292.)

Flagler, John H. Art of Forming Seamless Tubes. (401,415.)

Fox, Samson. Machine for Making Metal Tubes and Pipes. (258,740.)

Friedrich, Oscar, and *Schulte, Wilhelm.* Apparatus for Making Metal Tubes. (545,953.)

Friedrich, Oscar, and *Schulte, Wilhelm.* Process of and Apparatus for Making Holes Through Metallic Blocks. (536,278.)

Gardiner, Robert J. Piercing-Mandrel. (945,932.)

Gassen, Josef. Process and Rolling Mill for the Manufacture of Finished Seamless Tubes. (1,545,249.)

Görgen, Johann, and others. Machine for Forming Seamless Tubes. (549,356.)

Hall, Robert F. Means for Removing Seamless Tubes from Mandrels. (577,296.)

Harkins, James J., and *Orman, Otto F.* Apparatus for the Manufacture of Seamless Steel Tubes. (1,503,158.)

Harkness, Joseph C. Seamless-Tube-Rolling Mill. (988,569.)

Heckert, William. Rolling-Mill for Making Seamless Tubes. (429,623.)

Higgins, Campbell P. Machine for Forming Seamless Tubes. (961,128.)

Higgins, Campbell P. Machine for Forming Seamless Tubes. (961,129.)

Higgins, Campbell P. Machine for Forming Seamless Tubes. (961,130.)

Higgins, Campbell P. Machine for Forming Seamless Tubes. (961,131.)

Higgins, Campbell P. Machine for Forming Seamless Tubes. (961,132.)

Higgins, Campbell P. Machine for Forming Seamless Tubes. (961,133.)

Holinger, Emil F. Apparatus for Manufacturing Hollow Projectiles. (638,807.)

Holinger, Emil F. Dies for Manufacturing Seamless Tubes. (1,122,753.)

Holinger, Emil F. Manufacturing Seamless Tubes. (1,103,966.)

Horovsky, Zdenko. Apparatus for the Manufacture of Tubing. (529,910.)

Hughes, Wallace E. Method of Making Tubes. (1,223,282.)

Inshaw, John George, and *Inshaw, George Richard.* Apparatus for Use in Making Weldless Tubes from Hollow Blooms, Billets, and the Like. (1,263,251.)

Ivins, Ellwood. Machine for Manufacturing Seamless Drawn Tubes. (609,147.)

Ivins, Ellwood. Manufacture of Seamless Drawn Tubes. (601,966.)

Ivins, Ellwood, and *Griffiths, William.* Seamless-Tube-Rolling Machine. (651,714.)

Jack, Hartley H. Manufacture of Seamless Tubing. (562,728.)

Jackson, William U., and *Lloyd, Francis H.* Machinery for the Manufacture of Metallic Tubes, etc. (752,980.)

Kellogg, Charles. Machine for Rolling Seamless Tubing. (397,724.)

Kellogg, Charles. Machine for Rolling Tubes. (439,878.)

Kellogg, Charles. Machine for Rolling Tubes, Columns, etc. (278,340.)

Kellogg, Charles. Mandrel for Rolling Seamless Tubes. (424,213.)

Kellogg, Charles. Tube-Rolling Machine. (325,938.)

Kellogg, Morris. Apparatus for Making Seamless Tubing. (1,528,832.)

King, John H., and Others. Apparatus for Manufacturing Seamless Tubing. (719,231.)

King, John H., and Others. Apparatus for Manufacturing Seamless Tubing. (742,200.)

King, John H., and Others. Apparatus for Manufacturing Seamless Tubing. (740,442.)

Larson, Carl Gustaf. Tube-Rolling Mill. (526,157.)

Larson, Carl Gustaf. Support for Mandrel-Bars of Tube-Rolling Mills. (528,676.)

Ledermüller, Theodor. Rolling-Mill for Manufacturing Cylindrical Articles. (665,790.)

McIntosh, Frederick J., and *Thornburgh, William.* Machinery for Producing Seamless Metallic Tubes. (693,053.)

McTear, Balfour F. Apparatus for Drawing Hard-Metal Tubes. (880,563.)

McTear, Balfour F. Machine for Making Seamless Tubes or Hollow Articles. (700,361.)

McTear, Balfour F. Machinery for Making Seamless Metal Tubes, etc. (771,883.)

McTear, Balfour F. Manufacture of Seamless and Weldless Tubes or Hollow Bodies. (691,727.)

Mannesmann, Max. Art of Elongating Tubes. (721,214.)

Mannesmann, Max. Art of Rolling Tubes. (721,209.)

Mannesmann, Max. Art of Rolling Tubes. (721,210.)

Mannesmann, Max. Art of Rolling Tubes. (721,211.)

Mannesmann, Max. Art of Rolling Tubes. (721,213.)

(To be continued)

Structural Steel Building Welded*

A Description of the Procedure Followed in Erecting a Building in Which All Connections Were Welded Instead of Riveted. Comparison of the Cost of Both Methods

By JAMES H. EDWARDS†

DESIGNERS and fabricators of structural steel have been inclined to look with suspicion on welded joints, not because their experience with the new methods prompts them to mistrust the integrity of the union, but because of a tradition handed down for the time when steel took the place of wrought iron as a structural material. During this introductory period of steel, its quality was not as uniform as now and some unfortunate results were obtained when welds were made by the blacksmith method, using the forge furnace and hammer. Because of these experiences, specifications for steel structures rightly prohibited welding, or reduced unit values so low that it was not considered practicable to make safe and economical joints under the then existing circumstances.

The development of the present day welding art has been in the hands of trained scientists, with a knowledge of the metallurgy of the material to be joined, and the physical and chemical characteristics of the process. The art is beyond the experimental stage, and if welds are designed by those who know the safe limits under various conditions of stress and manufacture, and the welding be done with suitable equipment by trained operators, satisfactory joints can be made by any of the methods, gas or electric.

A description of various welding methods and their application has been very clearly and fully given by Prof. Comfort A. Adams in a paper on "Welding of Iron and Steel," presented before the meeting of this Institute on October 22, 1926.

The methods now in use are:

The Thermit—not adapted to structural steel.
Resistance—seam or spot—electric.
Fusion—either gas or electric.

The resistance method, by which welds are made by heating and pressing together a limited area of the surfaces to be joined, does not seem well suited for structural joints. The metal to be welded, usually by lap joints, is pressed between electrodes, ordinarily circular and of limited cross section to confine the electrical resistance to a small area. This area is heated under pressure to a welding heat and then consolidated by an increased pressure. To overcome the wear of the soft copper electrodes, projections in the surface to be welded may be made mechanically, either by embossing or by placing loose pieces called buttons between the contact surfaces. The electric current is thereby confined to these small areas, and the electrodes can be made somewhat large to withstand the welding pressure.

The apparatus for making spot welds so far developed is cumbersome. It should be fixed in position, not portable, and the work passed through the welder. This means special handling and assembling operations. By the welding apparatus so far introduced, the maximum total thickness of metal that can be satisfactorily joined is about 1 in.

The Fusion process, using either gas or electricity for heating the metal, is well suited to joining structural steel members. The tools and equipment, whether hand or machine, are easily portable. The work can be assembled and held in fixed position and the welding done either by hand or by machine, or if desired the machine can be fixed and the work moved.

Joints—The various types of joint used for structural steel can be readily made by the fusion process. The simplest and the one most commonly used up to the present time is the butt, where two edges of a plate are welded edge to edge. Depending on the thickness, the preparation of the metal edges varies from a straight edge. Lap joints may be made in various ways by laying a fillet or triangular shaped line of welding material along the edge of the parts to be joined.

In making any of these welds, the surfaces to be joined are heated to plastic state by the gas flame or electric arc, and the welding material is added by melting a wire of suitable material, usually low carbon steel, that unites with the fused joint of the parent or base metal. The deposited metal is cast steel, and its strength depends to some extent on the quality of wire used. Its elastic limit is a much higher proportion of the ultimate strength, and the reduction of area under stress much less, than that of structural steel.

One of the questions raised is what effect if any does the welding process have on the strength of the base material. It is generally conceded that for joints of ordinary thickness, when the steel has a carbon content below 0.25, there is no appreciable change in the strength of the parent material.

Because of the local heating of the parts, expansion difficulties are encountered, such as twisting, and buckling. Internal stresses may develop sufficiently to tear apart the pieces during the welding process. An experienced welder soon learns how to meet such expansion troubles as can be overcome, and to avoid the impossible. Material to be welded should be of uniform quality and free from segregation. Because of the necessity of limited small clearance of joints (usually not more than 3/16 in.) the edges may have to be finished and surfaces straightened.

The standard structural shapes now rolled have been designed to suit the use of rivets and bolts for making joints. These shapes are not the most suitable for the welding process. As the welding art becomes more used, shapes more economical and better adapted to the welding process doubtless will be demanded and furnished.

Tests of the strength of welds have been made of many commonly used joints, such as the butt joints used in ship and tank work. To a limited extent other tests of structural joints have been made. Practically all the specimens have been prepared so that the welds would develop the full tensile strength of the metal joined. The published tests indicate that this can be accomplished. While it is desirable in some cases to develop the full tensile strength of the parent material, this is not necessarily so. Structural engineers need unit values of the strength of welds, in order to properly proportion the joints of a structure to carry the stresses produced by the loads. Such tests are now being made under the direction of a committee sponsored by the National Research Council, and the American Bureau of Welding.

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†Assistant chief engineer, American Bridge Company, New York City.

Welding of parts of structural steel is no longer a process confined to repair of broken parts, an emergency agent. It has become an industry, and there are plants that do welding exclusively. Welded structural parts are gradually taking the place of castings in machinery construction, because greater strength is obtained at less cost. In the ornamental and architectural iron work industry, welding is a recognized process for joining parts. Structural fabricators have been somewhat conservative, because of an inborn prejudice against welding, and because the failure of an engineering structure would jeopardize life and property. While the time has not yet come to change completely from rivets to welds, fabricators could with safety and economy make use of welding in many ways in the ordinary run of fabricated steel.

Some completed welded structures have been erected, by parties for their own use, and by manufacturers and developers of welding apparatus. As examples, we mention, shop for C. B. & Q. R. R., Youngstown Welding Company, Linde Air Products Company, Barnes Wire Fence Company, and many structures fabricated by the Metropolitan Gas Company, Melbourne, Australia. The Morgan Engineering Company have used welding quite extensively in their shops, and they erected for others a two story garage structure at Canton, Ohio. Many examples of parts of structures have been described in the technical press and trade papers. An all welded five story shop building has recently been erected at Sharon, Pa., for the Westinghouse Electric & Mfg. Company. As this is probably the outstanding example up to the present time of welded building construction, a description somewhat in detail will be given of its design, fabrication, erection and cost.

The structure is a five story shop, 70 ft. wide, 220 ft. long, with eleven 20 ft. panels longitudinally, and three aisles transversely. In the lower story, one column is omitted for one floor to accomodate a runway for a traveling crane of three tons lifting capacity. The floors are of wood construction and carry a live load of 300 lbs. per sq. ft.

The building was designed as a standard riveted type. The steel skeleton frame consisted of solid rolled columns, and the floor framing of rolled beams, except the girders supporting the columns above the crane runway, which were riveted plate and angle girders. All floor supports were figured as simple beams or girders supported at the ends, carrying into the columns only vertical reactions.

A design was made for a welded structure to fulfill the same purpose and conditions. The distinguishing feature of the welded design was the floor framing, where advantage was taken of fixed end condition of beams and girders; these being figured as continuous members in flexure with a theoretical increase in load capacity of 50 per cent. In place of solid rolled column sections, American Bridge Company constant dimension plate and angle columns were used, so as to make beams framing between columns one length as far as possible. The beams were milled to length to obtain proper welding clearance, so the duplication was advantageous to both mill and fabricating shop.

The Westinghouse Company had previously made a comprehensive series of tests of different kinds of joints that might be encountered in a structure of this kind. The tests showed that it would be possible to develop the full strength of the members by welded joints. On the basis of the results of these tests, the detail joints of the Sharon Building were determined. These tests have been published in trade bulletins and technical papers and are available. The unit basis of joint design was a conservative value of 2,500 lbs. per lineal in. of fillet designated as 5/16 in., that is, a triangle whose right angle sides were 5/16 in. each. This unit corresponds to approximately 8,000 lbs. per sq. in. of contact weld surface.

Estimates of weight of steel of the two designs indicated a weight of 885 tons for riveted, and 790 tons for welded design, the saving being in the floor framing girders due to continuity feature heretofore mentioned. The cost estimates for steel of the two designs, using welding costs given by the Westinghouse Company, were not far apart.

The American Bridge Company being desirous to promote the welding of structural steel along rational lines, that is, by the co-operation of welding apparatus manufacturers and fabricators, undertook the work on the basis that the steel would be furnished at a fixed pound price for all material and work, except such material, apparatus and labor as were directly connected with the actual welding; that the customer would furnish the welding machines and welding wire and facilities for training welders; that all design and making of welds would be under the direct guidance of the customer's engineers and inspectors; and that the welding was to be done on a cost basis, the cost limited to an amount that would not make the total for steel erected exceed the estimated cost of the riveted design.

The American Bridge Company, to satisfy themselves that their welders could do the work, and to establish some procedure of operation for welding the large second floor girders, turned over to the welders some stock plate material with instructions that they try out their skill in making a similar girder. No attempt was made to select material for, or to design, a properly proportioned girder, only the welding of the joints being under consideration. The complete girder is made up of a 24 in. x ½ in. web with cover plates, with each flange of a 12 in. x 1¾ in. and a 9½ in. x 1⅝ in. full length. The girder was tested under load at the Bureau of Standards at Washington. It failed by the buckling of the web plate at its calculated yield point load, approximately 400,000 lbs. in the center. There were no weld failures until nearly the ultimate load of 800,000 lbs. was reached, when the web plate separated from the flange in one of the end panels.

After the shop work was finished and before shipment the steel was given a coat of oil. Paint should not be used when material is to be subsequently welded.

The field erection was handled in the usual manner with a locomotive crane on track placed in center of

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building. Each cross bent or frame was erected full height from base to roof as the crane was moved away from the raised portion. Some holes were provided in the connections to hold the material in place, but they were not enough to bring the members in true line. To plumb the skeleton and hold it wire rope guys were required from top to bottom at each cross bent and along each row of columns lengthwise for two bays. More guys were used than ordinarily for a riveted structure, and more careful alignment and adjustment was necessary to hold the structure and maintain welding clearances.

Aside from the difficulty in plumbing the frame and holding it in proper position by use of wire guys, instead of many drift pins in holes, the protection of the eyes of welders by shields and helmets, and the precautions necessary to avoid fire from sparks that might fall on the welders' clothing or inflammable material nearby, there were no unusual precautions other than those met on other field jobs. The position of welding, as far as possible, was arranged so that the metal could be deposited either on a horizontal or vertical surface, with the operator in a workable attitude. Over head welding should be avoided.

Costs of welding so far published seem to indicate that they were based on the actual time and material used, not taking due account of lost time, material waste, and overhead or general expense. Accurate cost records were kept of all operations connected with this work, particularly the welding. These are sumarized as follows:

The amount of welding done in the shop, taking as a basis of measurement 100 in. of single run 5/16 in. to ⅜ in. fillet, was approximately 244,000 lineal in., using 11,700 lbs. of 24 in. x 3/16 in. welding wire electrodes, and the cost was $4.18 per 100 lineal in. In the field, 129,500 lineal in. were welded, using 4,882 lbs. of 16 in. x 5/32 in. welding wire, and the cost was about $8.00 per 100 lineal in. The waste or loss of welding wire was 25 to 30 per cent and the weight of wire consumed ran about 1 per cent of the weight of the structural steel.

By comparing the actual costs of this welded structure with what a riveted one might be expected to cost, we find that there was a saving in material, due to design, of about 95 tons, or 11 per cent; the template making was a trifle less for welded; the shearing, marking, punching and finishing would be about 10 per cent less for welded, the assembling of parts for welding about 100 per cent more for welded, and the welding in the shop not including the use of electrical equipment shows a cost four times that of shop riveting. The raising of steel in the field, due to extra guying for alignment, was increased about 10 per cent and the field welding cost, not including the installation and use of electrical equipment, current and training of welders, was about the same as the riveting would cost. Prevailing shop and field labor rates were paid. Standard overhead expenses are included in the costs. After deducting the cost of training welders and making due allowance for other items that were included in this first job, and would disappear if shop were organized for welding, the additional cost of welded structure would be about $10.00 per ton, or about $8,000. The material saved by welded design was 95 tons at a cost of about $3,800, showing an excess cost of $4,200 over a riveted structure, not including use and maintenance of electrical equipment, welding wire and cost of training school.

Estimates, based on unit costs determined on this work, indicate that the continuity feature of the design as a whole cost more than the material saved, besides introducing into the design and fabrication some complicated and possibly undesirable features. Continuous or fixed end support members have their place in structures, but before being used to any great extent all engineering and cost features should be carefully weighed.

Based on the experience gained from this work it would seem that the all welded skeleton structure is not the most economic one.

By the fusion welding process joints can be made as strong as the base metal, and the full gross section of a tension member can be used, with no deduction for holes as when rivets are used. Due to the greater stiffness of end connection, and the ease with which component parts can be more rigidly held together, welded details of compression members increase their efficiency. By taking advantage of these favorable factors, and with the added advantage that will obtain when sections more suited to welding are rolled, there may be some saving in material that will more than offset the extra cost of welding.

Where existing structures require strengthening because of increased loading, material can be added more advantageously by welding than by the expensive method of drilling holes and driving rivets in awkward field positions; also when additions are made to structures, welded connections can be well and cheaply made with a minimum disturbance of walls and exposure of occupants. Furthermore, in favor of welding there are other considerations that might be given some weight aside from economy, such as the elimination of noise of riveting in thickly settled communities; another somewhat connected factor is the possibility of making welded connections, for resisting lateral forces such as wind, much simpler than the present cumbersome riveted brackets that interfere with the architectural treatment of exterior walls and interior finish. Welding can be used to supplement riveting and will eventually find its economical place.

Designers and fabricators of structural steel from many years of experience have learned the virtues and weaknesses of rivets and know how to use them to make safe and economical structures. They are now seeking the fundamental facts concerning the welding art on which they can base their determination of strength. It is generally accepted by those who have had any structural steel welding experience that safe and reliable welds can be made by a trained operator following a well defined procedure control. There is a demand for standard specifications and methods of making welds by the different processes. Values on some unit bases for the strength of welds of different types should be fixed. Some reliable way of controlling the mechanical and personal element used in making welds, and in testing the completed work, should be established. With these factors fixed by scientific research and made available to the industry, the manufacturers of welding apparatus, the advocates of welding as a method of joining steel parts, and the fabricators of structural steel, all co-operating to solve an engineering and economic problem, will doubtless make great progress in the development of the art of welding in the structural steel industry.

Effect of Gas on Heat Resisting Steels*

A Recognized Authority on Steel Presents a Comprehensive Dissertation on the Ability of Steels, of Varying Compositions, to Withstand Heat and the Corrosive Action of Gases

By DR. W. H. HATFIELD†

DURING recent years the interest in heat-resisting steels has grown rapidly, and several notable advances in this particular field have been accomplished. However, as Monypenny has recently stated, little has been published with regard to some of the complex steels now being used which would enable one to compare them with the simpler steels, and thus to judge the intrinsic effect of the extra alloying elements. A review of the work to date would indicate that much fundamental knowledge remains to be determined, and the author trusts that this account of investigations carried out in the Brown-Firth Research Laboratories may be considered a useful contribution to the subject.

The researches to be described had a double object. In the first place, they were naturally designed with a view to assisting in the production of better heat-resisting steels; but, in the second place, it was hoped that fundamental data, useful in elucidating the nature of the attack from which steels suffer when exposed to the atmosphere and industrial gases at high temperatures, would be obtained.

The achievement of improvement in the characteristics the steels might perhaps be considered a comparatively simple matter of standardizing the approved gaseous influences under standard and controlled conditions of heating, and then submitting to such conditions suitably prepared samples of steels of various compositions and in various conditions. Such, indeed, was the line of attack.

As regards the problem of throwing light upon the nature of the attack at high temperatures, it must at once be conceded that this is extremely difficult. It can be approached from the standpoint of corrosion at ordinary temperatures; and, indeed, in the literature of the subject, it is common to find the rustless and heat-resisting steels dealt with together. The explanation of the phenomenon of resistance, or, to be more accurate, relative resistance at high temperatures, may be similar to that of the phenomenon of rust resistance, the resistance being determined by the formation, or otherwise, and the characteristics of a protective film of a composition determined, in the first place, by the analysis of the steel, and, in the second place, by the composition of the gaseous media. Experimentally, the subject is difficult, if only on one account: great care may be taken in purifying the gases used to produce the atmosphere required, but it should always be remembered that all the steels contain carbon, sulphur, and hydrogen in varying, though in the latter cases small, percentages, and at the high temperatures considered, these elements react with the gaseous medium. Thus small quantities of the products which such elements may form will be present, and will require to be considered in any theoretical handling of the results. The importance of such percentages of substances, other than those directly under study, has been well emphasized in the investigations of corrosion at ordinary temperatures by Friend, Evans, and others; it was

TABLE I—ANALYSES OF MATERIALS

Symbol	Material	Condition	C %	Mn.%	Si %	S %	P %	Cr %	Ni %	W %	Cu %	Fe %	Co %
A	Pure iron	Normalized 950° C.....	0.04	0.01	0.01	Nil	Nil	.....	0.02	.....	.....	99.92	.....
B	Chromium	As cast	0.16	0.02	0.40	.....	.....	98.10	.....	.....	.....	1.30	.....
C	Nickel	As cast	0.04	....	.....	.....	.....	.....	99.58	.....	.....	0.38	.....
D	Cobalt	As cast	0.54	0.02	0.14	0.66	.....	.....	2.83	.....	.....	0.49	95.66
E	Copper	Annealed	....	....	.....	.....	.....	.....	.....	.....	99.95	0.05	.....
F	Tungsten	Hard drawn	....	Nil	.....	.....	.....	.....	.....	99.99	.....	......	.....
G	Mild carbon steel	Normalized 900° C.....	9.17	0.67	0.18	0.012	0.018	.....	0.25	.....	.....	98.70	.....
H	3% nickel steel	Oil-hardened 850° C., tempered 630° C.....	0.34	0.60	0.29	0.021	0.012	.....	3.25	.....	.....	95.49	.....
I	36% nickel steel	Air-cooled 950° C.......	0.24	0.40	0.16	0.020	0.015	0.09	36.90	.....	.....	62.17	.....
J	Silicon-chromium steel	Air-cooled 1050° C., tempered 850° C........	0.50	0.37	3.04	0.01	0.01	8.28	0.16	.....	.....	87.63	.....
K	Chromium steel	Oil-hardened 1000° C., tempered 800° C.....	0.32	0.25	1.32	0.009	0.016	13.12	0.29	.....	.....	85.67	.....
L	Chromium steel	Air-cooled 900° C.....	0.09	0.39	0.37	0.011	0.015	18.53	0.26	.....	.....	80.334	.....
M	Chromium-nickel steel	Air-cooled 1150° C.....	0.11	0.34	0.21	0.011	0.013	14.84	10.16	.....	.....	74.316	.....
N	Chromium-nickel steel	Air-cooled 1150° C.....	0.12	0.28	0.31	0.008	0.014	17.74	8.06	.....	.....	73.47	.....
O	Nickel-chromium steel	As rolled	0.35	1.36	0.21	0.021	0.013	10.90	35.15	.....	.....	52.00	.....
P	Chromium - nickel - silicon steel	Water-quenched 1000°C.	0.58	0.36	4.00	0.020	0.017	15.54	8.14	.....	.....	71.43	.....
Q	Chromium - nickel - tungsten steel	As rolled	0.30	0.52	1.46	0.02	0.017	17.74	7.0	4.23	.....	68.713	.....
R	Nichrome	Air-cooled 950° C......	0.06	0.89	0.71	.....	.....	11.69	60.40	.....	.....	26.24	.....
S	Cast iron	As cast .... Gr. C. C.C.	2.52 0.68	0.21	1.13	0.125	0.58	.....	.....	.....	.....	94.24	.....
T	15% silicon iron	As cast .... Gr. C. C.C.	0.76 0.03	0.72	14.30	0.045	0.731	.....	.....	.....	.....	83.92	.....
U	Monel metal	Hot-rolled	0.14	1.00	0.03	.....	.....	.....	69.98	.....	27.17	1.67	.....

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†Sheffield, England.

established by Ariens Kappers in 1872 that sodium and potassium did not oxidize in dried oxygen, by Cooper in 1882 that chlorine was without action on several metals in the absence of water; while Baker in 1883 established the astonishing fact that purified charcoal could be heated to redness in dried oxygen without burning.

Materials Tested

In Table I will be found a complete list of the analyses of the metals, steels, irons, and alloys which formed the subject of experiment, and for convenience the symbol given for each material is used throughout the paper. In all cases, unless otherwise stated, the samples were approximately 1 cm. in diameter, and weighed about 20 grm.; the index figure given is the increase in weight in milligrams per square centimeter of surface. A standard finish, viz., 00 emery, was given to all the cylinders. Thus the data obtained are all strictly comparable. The duration of the exposure was 24 hours.

Experimental Results

Atmospheric Tests—It was thought advisable, in the first place, to test out, at a standard temperature of 900 deg. C., the influence of the atmosphere, pure, and also modified by the presence of sulphur dioxide, carbon dioxide, and steam, upon ordinary mild carbon steel (G). This was done, with the extremely interesting results shown in Table II:

TABLE II

Influence of the Atmosphere, Pure and with Various Additions, on a Mild Carbon Steel (G)

Condition of Atmosphere	Weight of sample Grm.	Increase of weight Grm.	Index Figure
Pure air	21.7344	0.5800	55.238
Atmosphere	21.0978	0.6117	57.166
Pure Air + 2% SO_2	20.8553	0.6843	65.173
Atmosphere + 2% SO_2	19.7816	0.6905	65.762
Atmosphere + 5% SO_2 + 5% H_2O	20.4646	1.5242	152.420
Atmosphere + 5% CO_2 + 5% H_2O	22.4074	1.1048	100.436
Pure air + 5% CO_2	22.1328	0.9303	76.884
Pure air + 5% H_2O	20.3436	0.8089	74.211

It is clearly evident, from this set of experiments, how profoundly the attack upon a typical mild carbon steel is increased by the presence of SO_2, CO_2, and H_2O.

It was decided next to determine the behavior, under the same conditions of experiment, of a chromium-nickel rustless steel (N), containing 18 per cent of chromium and 8 per cent of nickel, which behaved excellently as regards resistance to corrosion at ordinary temperatures. The results obtained under conditions indentical with those employed in testing the mild steel are shown in Table III:

TABLE III

Influence of the Atmosphere, Pure and with Various Additions, on a Chromium-Nickel Rustless Steel (N)

Condition of Atmosphere	Weight of sample, Grm.	Increase of weight, Grm.	Index Figure
Pure air	34.7058	0.0062	0.403
Atmosphere	34.5083	0.0071	0.461
Pure air + 2% SO_2	25.5649	0.0107	0.859
Atmosphere + 2% SO_2	23.4008	0.0136	1.126
Atmosphere + 5% SO_2 + 5% H_2O	23.7758	0.0439	3.578
Atmosphere + 5% CO_2 + 5% H_2O	31.5332	0.0678	4.582
Pure air + 5% CO_2	31.3954	0.0176	1.175
Pure air + 5% H_2O	31.1554	0.0516	3.240

It will be seen that a steel resistant at ordinary temperatures ceases to be completely so at 900 deg. C., but that the order of resistance is very much greater than in the case of mild steel. Again the influence of SO_2, CO_2, and H_2O is to be noted.

It was realized that it was desirable to endeavor to couple up the response at ordinary temperatures with that at 900 deg. C.; but to do this satisfactorily with the whole of the gaseous media was a very big task, and it was therefore decided simply to experiment, at this stage, with the ordinary atmosphere, but using three steels—i. e., a mild carbon steel, a 14 per cent chromium steel, and the one used in the previous experiment, containing 18 per cent of chromium and 8 per cent of nickel. The results will be found in Table IV:

TABLE IV—Atmospheric Tests on Three Steels

Testing Temperature ° C.	Mild steel (G) Index figure	Chromium steel (K) Index figure	Nickel-chromium steel (N) Index figure
100	Nil	Nil	Nil
200	0.033	0.013	Nil
300	0.127	0.04	0.020
400	0.454	0.081	0.040
500	0.622	0.093	0.040
600	4.636	0.200	0.133
700	11.917	0.399	0.223
800	44.914	0.767	0.395
900	57.166	1.073	0.461
1000	135.777	66.671	21.820
1100	208.000	165.270	72.301
1200	399.877	261.000	177.66

It is clear from these figures that the chromium steel (K) is markedly superior to the mild steel (G), but that while both steels are unaffected at 1000 deg. C. they are both attacked at 200 deg. C., though in different degrees. There is a great acceleration in the attack on mild steel on approaching 600 deg. C., but the similar acceleration in the case of the chromium steel is postponed until 900 deg. C. A comparison of the results obtained with the nickel-chromium steel (N) indicates clearly the increased resistance obtained by the further modification in composition. The outstanding feature of these experiments, to the author's mind, is the definite attack obtained at such low temperatures in the case of all three steels. According to common conceptions, the zone of temperature from 200 deg. C. to 500 deg. C. would hardly be associated with the heat-resisting problem under consideration, yet clearly the attack appears to be of the same nature as that which takes place at the higher temperatures, but simply of a different order.

Influence of Industrial Gases—It is somewhat difficult to approximate to industrial and service conditions when performing laboratory experiments. The purpose in view in the next set of experiments was to test, in an empirical manner, the response of a number of available materials to exhaust gases and furnace atmospheres. With that object, the conditions of experiment selected were:

(a) The atmosphere of an unenclosed gas muffle. A sample taken during the experiments analyzed as follows:

	Per cent
Nitrogen	67.7
Oxygen	1.34
Carbon dioxide	4.75
Steam	21.10
Sulphur dioxide	0.003
Carbon monoxide	5.10

(b) A "complex" gas of the following composition:

	Per cent
Nitrogen	72.95
Oxygen	5.0
Carbon dioxide	12.0
Steam	10.0
Sulphur dioxide	0.05

This composition of the "complex" gas was arbitrarily arrived at by considering the products of combustion from various fuels and sources, as shown in Table V:

TABLE V—THE PRODUCTS OF COMBUSTION FROM VARIOUS FUELS

Origin of Gases	Per cent by volume at 100° C. CO_2	CO	H_2O	O_2	SO_2	N_2	Authority and Remarks
Coal-fired boiler	10.7	Nil	4.5	6.10	0.04	78.70	S. Yorkshire bituminous coal + 50% excess air. C, 74.75; H_2, 4.70; O_2, 9.78; N_2, 1.34; SO_2, 0.96; H_2O, 5.00; ash, 3.47%.
Siemens furnace	13.3	Nil	12.2	3.55	0.10	70.95	F. Clements[1]
Motor-car (petrol C_6H_{14})	11.2	Nil	13.1	1.00	......	74.7	Royal Automobile Club, allowing 1% free oxygen in exhaust.
Motor-car (benzol, C_6H_6)	14.7	Nil	7.3	1.00	......	77.0	Royal Automobile Club, allowing 1% free oxygen in exhaust.
Gas-engine (town's gas)	7.3	Nil	16.8	3.5	0.007	72.5	Sheffield Gas Co., assuming 25% excess air, and 10 grains S per 100 cu. ft.
Gas-engine (blast-furnace gas)	31.0	Nil	1.7	2.3	Practically nil	65.0	F. Clements, Park Gate Iron & Steel Co., blast furnace gas. CO_2, 8.25; CO, 28.5; H_2, 2.00; N_2, 61.25; + 25% excess air.
Annealing furnace (inside)	15.7	....	6.6	Nil	0.06	77.70	Neutral flame conditions.

In both sets of experiments the temperature selected was 900 deg. C. and the period of exposure 24 hours, thus making the data comparable with the previous results.

In Table VI will be found the figures obtained.

TABLE VI—The Influence of Industrial Gases

Symbol	Material	Complex gas at 900° C. Index figure	Muffle at 900° C. Index figure
A	Pure iron	114.012	95.34
B	Chromium	2.051	1.00
C	Nickel	5.222	16.83
G	Mild carbon steel	80.225	73.104
H	3% Nickel steel	72.893	43.30
I	36% Nickel steel	30.058	27.70
J	Silicon-chromium steel	0.84	0.506
K	Chromium steel	18.319	20.50
L	Chromium steel	1.252	1.38
M	Chromium-nickel steel	6.000	3.84
N	Chromium-nickel steel	2.699	0.326
O	Nickel-chromium steel	2.534	1.01
P	Chromium-nickel-silicon steel	0.689	0.061
Q	Chromium-nickel-tungsten steel	0.43	0.175
R	Nichrome	1.397	0.765
S	Cast iron	86.000	33.80
T	15% Silicon iron	78.434	13.734
U	Monel metal	68.676	1.55

On considering the influence of these industrial gases on the various samples, it will be seen that, although only one temperature, 900 deg. C., is being considered, there are interesting facts to be discerned. Pure iron (A), as would be expected, is very badly attacked, chormium (B) is very resistant, while compared with iron, nickel (C) gives a good account of itself. Mild carbon steel (G) is more resistant than the pure iron (A), possibly on account of the protection afforded by its carbon content. The influence of nickel is well illustrated by the steels containing 3.0 and 36 per cent respectively (H and I), and it will be seen that the effect is undoubtedly to produce increased resistance. The silicon-chromium steel (J) is, curiously, much more resistant even than chromium. In the two chromium steels (K and L), 13 per cent of chromium undoubtedly had a profound influence upon the behavior of the alloy, but by increasing the percentage to 18.0 a resistance of the same order as that of chromium (B) is obtained. On studying the steels (M), (N), and (O), containing both nickel and chromium, a high but variable resistance due to the variable proportions of the elements is found; (N) gives the most satisfactory results, but it is interesting to compare (M) and (K), in which the chromium is roughly comparable, but in which there is the outstanding variable of 10 per cent nickel in (M), and a greatly improved resistance. The optimum results obtained from (N) are seen to be still further improved in the cases of either (P) or (Q) by the addition of silicon and tungsten respectively. Nichrome, as would be expected, gives very good results, but it is not equal to either (J), (P), or (Q), which are charged with a far smaller amount of the added metals. The cast iron (S), the 15 per cent silicon iron (T), and the Monel metal results are of interest by way of comparison with the general series.

It is to be deduced from these figures that the resistance of iron is greatly increased by the addition of either chromium, or nickel, or both; the addition of silicon or tungsten still further increases the resistance of such alloys.

A comparison of these results would indicate quite clearly that the "complex" gas, as a general representative of products of combustion, is much more active in attacking the samples than the muffle atmosphere; the latter series of tests was introduced to enable a comparison with the other more "experimental" tests to be made in an empirical practical manner. There are, it should be noted, two exceptions, in which the attack was greater in the muffle atmosphere, namely, metallic nickel (C) and the chromium steels (K) and (L). Broadly speaking, the greater activity of the "complex" gas must be accepted, and it is, therefore, of interest to compare the two gaseous atmospheres. The "complex" gas contains more carbon dioxide, oxygen, and sulphur dioxide, and very much less steam. The author is of the opinion that the increased attack is due to the increased percentages of CO_2 and SO_2, particularly of the latter. The anomalous behavior of the nickel and of the chromium steels is difficult to explain, and it was considered desirable to conduct a systematic investigation in which the fundamental reactions between the metals, and subsequently between the steels, irons, and alloys, and the individual gases could be studied.

TABLE VII
The Effect of Oxygen on Various Metals at Various High Temperatures

		Index Figure			
Symbol	Material	700° C.	800° C.	900° C.	1000° C.
A	Pure iron	51.119	59.535	124.271	141.60
B	Chromium	0.469	0.974	2.241	6.309
C	Nickel	0.957	1.150	2.823	9.693
D	Cobalt	3.72	4.387	93.132	119.474
E	Copper	11.967	19.075	43.954	....
F	Tungsten	46.162	275.412	376.22 *	....

*Completely converted to WO_3.

TABLE VIII
The Effect of Steam on Various Metals at Various H'gh Temperatures

		Index Figure			
Symbol	Material	700° C.	800° C.	900° C.	1000° C.
A	Pure iron	62.239	84.710	57.533?	178.390
B	Chromium	0.05	0.366	1.167	2.110
C	Nickel	0.336	0.424	1.382	4.385
D	Cobalt	0.81	0.824	25.896	73.549
E	Copper	3.254	12.730	15.296	....
F	Tungsten	2.077	17.698	179.209	....

TABLE IX
The Effect of Carbon Dioxide on Various Metals at Various High Temperatures

		Index Figure			
Symbol	Material	700° C.	800° C.	900° C.	1000° C.
A	Pure iron	58.739	72.248	113.268	175.515
B	Chromium	0.271	0.336	1.333	3.084
C	Nickel	0.391	0.872	3.561	4.558
D	Cobalt	2.682	5.385	44.326	15.048
E	Copper	6.547	9.893	12.255	....
F	Tungsten	13.919	20.316	13.900*	....

*Oxide formed, but some volatilization occurred.

TABLE X
The Effect of Sulphur Dioxide on Various Metals at Various High Temperatures

		Index Figure			
Symbol	Material	700° C.	800° C.	900° C.	1000° C.
A	Pure iron	35.419	79.104	Completely conv'd	
B	Chromium	0.158	0.392	3.253	3.568
C	Nickel	92.283	366.730*	83.729†	2.595‡
D	Cobalt	59.767	102.791	163.297	289.821
E	Copper	0.125	0.128	0.195	....
F	Tungsten	47.048	72.784	29.000§	....

*Scale disintegrated. †Scale firmly adherent. ‡Scale very firmly adherent. §Partial loss due to volatilization.

Fundamental Experiments—The production of better heat-resisting steels, as has been shown, is dependent upon the influence of the added elements upon the properties of the resultant alloy. It is, therefore, of interest to study the response of pure iron, and of the other elements normally employed, to simple gaseous influences at increasingly high temperatures. The literature contains a paucity of data in reference to these matters. Pilling and Bedworth[2] discussed the oxidation of iron at high temperatures in a particularly interesting manner. Milbauer[3] is responsible for a very intriguing suggestion, that iron is not acted upon by oxygen at high temperatures and pressures under "dry" conditions. Newton Friend[4] made a painstaking attempt to determine the response of iron to steam at high temperatures, and his conclusions may be summarized in the statement that a reaction takes place at temperatures over 243 deg. C. with the liberation of hydrogen. As to whether or not his investigation was carried out under satisfactory conditions from the theoretical point of view is not clear, but is doubtful owing to the unavoidably incomplete purity of his iron (iron foil, 99.4 per cent iron). From an interesting paper by Schröder and Tammann[5], it seems reasonable to assume that air or oxygen would have the same oxidizing effect on iron, although a consideration of the data in the present paper shows the comparative effect to vary with the temperature.

The experimental pieces of pure iron (A), chromium (B), nickel (C), cobalt (D), copper (E), and tungsten (F), were exposed for 24 hours to oxygen, steam, CO_2, and SO_2 at 700, 800, 900, and 1000 deg. C. The measure of the attack (index figure) was the increase in weight in milligrams of the specimen per square centimeter of surface. The figures obtained in this series of experiments will be found in Tables VII to X. A consideration of the results obtained leads to the following comments:

1—The order of the resistance to attack, if broadly surveyed, is much the same whether the medium is oxygen, H_2O, or CO_2—e. g., chromium, nickel, cobalt, copper, iron, tungsten. The low resistance of tungsten to these gases is in conformity with the results of Sir Robert A. Hadfield's experiments[6], published some years ago, and its behavior in this respect is particularly interesting in view of the value of tungsten in heat-resisting steels as generally known, and as shown in Table XI to XIV. There are notable exceptions in the order of resistance, as seen in the case of SO_2, in which it will be found that cobalt is badly attacked at all temperatures, the attack increasing progressively with rising temperatures, while in the case of nickel the attack is very heavy at 800 deg. C., but decreases with higher temperatures, so much so that at 1000 deg. C. the attack is almost negligible. In the case of nickel this curious effect is apparently due to the nature of the scale formed; that formed at 1000 deg. C. is very firmly adherent.

2—The extent of the attack varies at different temperatures for the different metals, so that the order of resistance of the different metals to gaseous media is not necessarily the same at all temperatures. This is well illustrated by cobalt and copper in steam, oxygen, and CO_2; while the attack increases with temperature, it will be seen that raising the temperature from 800 deg. C. to 900 deg. C. causes such an abnormal acceleration in the attack on the cobalt as to reverse the order of resistance.

3—Increase in the attack, as the temperature is raised, is general, but not without exception, as is seen in the case of nickel in SO_2. The experiments occasionally showed that the character of the scale had much influence. The increase in attack does not always show a reasonably proportional relationship to the increase in temperature, the attack in several cases becoming abnormally accelerated with increasing temperature.

Having determined the response of the individual metals to these gases at high temperatures, it is of great interest to study the behavior of steels of various compositions, produced by alloying them in different proportions.

TABLE XI

The Effect of Oxygen on Steels and other Alloys at Various High Temperatures

Symbol	Material	Index Figure 700° C.	800° C.	900° C.	1000° C.
G	Mild carbon steel ..	10.422	29.760	83.411	170.860
H	3% Nickel steel ...	40.032	51.240	67.025	230.268
I	36% Nickel steel ..	4.122	9.727	14.039	25.548
J	Silicon-chromium steel	0.260	1.668	2.07	2.94
K	Chromium steel ...	0.223	1.904	2.789	91.30
L	Chromium steel ...	0.600	0.739	1.895	2.886
M	Chromium-nickel steel	0.64	1.138	4.080	43.577
N	Chromium-nickel steel	1.079	1.047	2.707	5.659
O	Nickel-chromium steel	1.736	7.285	11.667	19.305
P	Chromium-nickel-silicon steel	0.168	0.339	1.262	1.806
Q	Chromium-nickel-tungsten steel	0.033	0.050	0.202	4.489
R	Nichrome	0.243	0.491	0.764	1.778
S	Cast iron	11.773	56.767	129.113	427.546
T	15% Silicon iron ..	1.447	3.932	4.354	78.651
U	Monel metal	1.728	......	108.602	....

TABLE XII

The Effect of Steam on Steels and other Alloys at Various High Temperatures

Symbol	Material	Index Figure 700° C.	800° C.	900° C.	1000° C.
G	Mild carbon steel ..	3.657	21.970	74.932	231.051
H	3% Nickel steel ...	8.693	35.862	46.113	91.914
I	36% Nickel steel ..	3.159	13.381	36.202	54.541
J	Silicon-chromium steel	0.344	0.535	0.946	1.355
K	Chromium steel ...	0.520	0.573	14.913	39.841
L	Chromium steel ...	0.235	0.583	2.031	3.260
M	Chromium-nickel steel	0.465	1.875	19.944	43.439
N	Chromium-nickel steel	0.24	0.50	6.14	17.456
O	Nickel-chromium steel	1.305	2.044	6.153	16.027
P	Chromium-nickel-silicon steel	0.100	0.266	0.926	1.496
Q	Chromium-nickel-tungsten steel ...	0.098	0.305	0.370	2.765
R	Nichrome	0.227	0.303	1.410	1.434
S	Cast iron	22.615	46.493	94.093	238.353
T	15% Silicon iron ..	2.20	92.976	210.487	418.304
U	Monel metal	0.636	......	18.927	....

The Response of the Steels, Irons, and Alloys under the same Conditions — It will be seen from Tables XI to XIV that the very interesting set of commercial steels, irons, and alloys have been studied under like experimental conditions; in each case the exposure to the gaseous atmosphere lasted 24 hours at the temperature selected, as in the previous experiment.

Commencing with ordinary mild steel (G) for comparative purposes, the influence of the addition of nickel can be judged from samples (H) and (I), which contain 3.0 and 36 per cent respectively of that element. The next steel is the well-known valve steel, containing 8 to 9 per cent of chromium, with 3 per cent of silicon (J). Steels (K) and (L) contain 13.0 and 18.0 per cent of chromium respectively, and therefore enable judgment to be passed upon the influence of the latter element. The next steels in the series, (M), (N), and (O), contain both nickel and chromium, but with those elements in different proportions. Steels (P) and (Q) are of particular interest, as showing how tungsten and silicon respectively modify the response of the chormium-nickel compositions similar to that found in steel (N). Nichrome is added owing to its well-deserved reputation for high-temperature work. Cast iron is included for comparison with mild steel, whilst the 15 per cent silicon iron is included owing to its acid-resisting properties at ordinary temperatures. Monel metal containing, as it does, a similar nickel content to nichrome is added for that reason.

TABLE XIII

The Effect of Carbon Dioxide on Steels and other Alloys at Various Temperatures

Symbol	Material	Index Figure 700° C.	800° C.	900° C.	1000° C.
G	Mild carbon steel .	10.025	36.738	74.916	93.460
H	3% Nickel steel ...	9.845	29.155	50.818	151.339
I	36% Nickel steel ..	2.783	9.995	25.395	30.734
J	Silicon-chromium steel	0.245	0.213	0.426	0.841
K	Chromium steel ..	0.810	0.870	16.045	62.283
L	Chromium steel ..	0.235	0.757	2.889	2.948
M	Chromium-nickel steel	1.427	2.094	12.408	37.008
N	Chromium-nickel steel	0.391	1.080	3.254	5.85
O	Nickel-chromium steel	1.054	2.205	7.328	11.654
P	Chromium-nickel-silicon steel	0.122	0.224	0.550	0.584
Q	Chromium-nickel-tungsten steel ...	0.148	0.148	0.317	0.922
R	Nichrome	0.411	0.438	0.548	1.134
S	Cast iron	13.953	18.547	21.133	40.568*
T	15% Silicon steel..	173.941†	1.523	5.814	29.473
U	Monel metal	2.60	......	21.203	....

*Thin film, dark grey adherent.

†Abnormal local expansion resulting from "growth."

TABLE XIV

The Effect of Sulphur Dioxide on Steels and other Alloys at Various High Temperatures

Symbol	Material	Index Figure 700° C.	800° C.	900° C.	1000° C.
G	Mild carbon steel.	9.857	41.641	177.007	.......*
H	3% Nickel steel..	30.192	450.675	700.13	.......*
I	36% Nickel steel.	20.120	141.315	199.112	256.447
J	Silicon-chromium steel	0.52	1.275	4.550	3.235
K	Chromium steel .	0.398	1.041	9.933	58.616
L	Chromium steel .	0.453	0.545	0.823	1.433
M	Chromium-nickel-steel	1.055	1.16	1.720	3.748
N	Chromium-nickel-steel	1.432	1.648	1.883	2.633
O	Nickel-chromium steel	0.293	0.414	0.417	7.939
P	Chromium-nickel-silicon steel ...	0.380	0.600	1.149	2.412
Q	Chromium-nickel-tungsten steel ..	0.204	0.399	0.539	0.829
R	Nichrome	0.33	5.044	55.624	91.104
S	Cast iron	6.757	33.973	85.360	.......*
T	15% Silicon steel.	1.402	1.920	4.867	160.396
U	Monel metal	43.904	....	.......*	....

*Converted.

The attack on the mild carbon steel (G) is heavy in all the four gaseous media. The addition of nickel produces anomalous results. It will be remembered that in the complex industrial gas, and in the muffle atmosphere, the 3 per cent and 36 per cent nickel steels (H) and (I) gave materially improved results, whereas, when the individual gases are considered, the 3 per cent nickel steel (H) gives a worse response in the lower range of temperature than mild steel in oxygen and steam, and much worse in SO_2. The 36 per cent nickel steel (I) gives a superior result in oxygen, steam, and CO_2, but in SO_2 the attack is again extremely heavy. The silicon-chromium steel (J) is comparatively very resistant in all four gases at all the temperatures dealt with. Turning to the chromium steels (K) and (L), it will be seen that in each medium a substantial increase in resistance is obtained, and that this resistance is greater with the higher percentage of chromium. The three steels containing chromium and nickel in different proportions (M), (N), and (O) are again of particular interest, and the results definitely indicate that there is an optimum balance of these elements for maximum resistance to the gases in conformity with the results given in Table VI. The steels (O) and (P), to which silicon and tungsten respectively have been added, have an enhanced resistance, taking the results all round. The nichrome, while behaving well in oxygen, steam, and CO_2 fails badly in SO_2 at the higher temperatures. As regards the other examples, perhaps the only point that need be noted is the substantial resistance of the 15 per cent silicon iron in SO_2 up to 900 deg. C.

A General Consideration of the Results

The literature of this subject will be found to contain several interesting papers dealing with the resistance of steels to oxidation. Dickenson[7] studied the differential effect on several steels and alloys at various temperatures. McCormick[8] dealt with the effect of the furnace atmosphere in producing scale on steels of varying carbon content. There are several papers dealing essentially with valve steels; Aitchison[9] set forth the value of chromium steels, while Grard[10], after an interesting description of various tests, claimed excellent properties for chromium-silicon steel. Mahoux[11] was responsible for an interesting metallurgical survey, and Henshaw[12] has made a review of the position to date. The latter author gave much valuable data concerning the composition and characteristics of heat-resisting steels in current use for meeting the onerous conditions imposed on aero-engine valves, and discussed the chromium, chromium-silicon, nickel-chromium, cobalt-chromium, and nickel-chromium-tungsten steels.

In generally surveying the data contained in the present paper, it is desirable to go back to a consideration of the figures given in Table VI. Therein will be found a quantitative indication of the degree of resistance of iron, chromium, and nickel in the first place, and then of the various types of industrial materials, to the "complex" gas and the muffle atmosphere at 900 deg. C. In the course of the experiments, it became clear that different gaseous media produced different results, but in the two gases dealt with in Table VI the corroding medium is reasonably representative of those influences for resisting which better compositions of steel are being sought. It is clear that the complex gas, representing as it does the industrial products of combustion, is more active in attacking the materials than the muffle atmosphere, which, as will be seen, not only consists of some unburnt combustibles, but also contains a definitely less proportion of sulphur dioxide. As a result of this research, the author holds the view that steam and SO_2 in the gases materially increase the difficulties of withstanding their action. Indeed, Kayser[13] has shown that in the case of nichrome and similar alloys, the resistance is very materially lowered by the presence of SO_2; while Ulick Evans[14] emphasizes the serious effects due to the SO_2 produced even in the combustion of coal-gas. It will be clear, therefore, that SO_2 resulting from the fuels used is one of the essential influences which the metallurgist is called upon to combat.

A survey of the data presented results in the detection of several anomalies of such consequence that it is evident that one cannot deduce, from the behavior of the constituent metals and elements, what the response of the alloy produced will be under a given set of experimental or service conditions. As a result of an interesting research in this field, it was stated, for instance, by Utida and Sato[15] that the attack on the alloy was greater as the iron content was increased. The author's data certainly demonstrates that such is not the case; it is shown that some alloys rich in iron have very much greater resistance than others containing less of that element.

The protective action of chromium is generally confirmed. The alloying of chromium with iron in the production of rustless and heat-resisting steels has been well dealt with in technical literature. The patent history of England and other countries also yields much information. The work of Brearley, Haynes, Pasel, Becket, the author, and others laid a sound foundation to the knowledge of that particular field. An interesting paper by McQuigg[16] discusses the influence of chromium in increasing the heat-resistance of steels, while the American Society for Testing Materials Symposium of 1924 did much to focus attention on the subject, notable papers being given by Johnson and Christiansen, Hunter and Jones, and Fahrenwald.

The American Symposium, to which reference has just been made, has also done much to extend the use of alloys containing nickel in addition to chromium, thus encouraging the utilization of the additive advantage of that element. The apparently anomalous effect of nickel in assisting in the protection of the steel of which it is a constituent may probably be explained by the influence of that element in causing the formation of a partilcular kind of protective layer: it is certainly an outstanding fact (see Table X) that with pure nickel in SO_2 there was a heavy attack at 800 deg. C., but that the attack diminished materially at 900 deg. C., and became practically negligible at 1000 deg. C. That nickel is a valuable element in these heat-resisting steels has also been established by other investigators. Sir Robert Hadfield[17], while giving no details of the precise analysis of the steels which he discussed, went so far as to suggest that the inclusion of nickel was responsible for a great step forward. Monypenny[18] described the increased resistance due to the addition of this element; and the same deduction is also to be made from the paper by Elliott and Willey[19].

The influence of silicon and tungsten in further increasing the resistance would appear to be fully established. In the case of tungsten this effect is certainly anomalous, since, as previously mentioned, the experiments disclose an abnormal attack in oxygen, a heavy attack in steam, but a materially diminished attack in CO_2 and SO_2. It might, of course, be deduced that the additive protection accorded by the metal is in line with its behavior towards the anhydrous acids CO_2 and SO_2, particularly the latter.

The main feature of this paper is the attempt to establish quantitatively the fact that these added elements do indeed produce steels which satisfactorily resist attack at high temperatures, and amongst such can safely be cited certain compositions in the chromium, the silicon-chromium, chromium-nickel, chromium-nickel-silicon, and chromium-nickel-tungsten series. Some of these steels have extremely satisfactory characteristics as regards resistance to corroding media under the conditions studied, and are fitted for much wider service than that in which they are at present employed.

In preparing this paper the author has studiously kept to the problem of corrosion-resistance at high temperatures, and has not complicated the consideration of these materials by dealing with the mechanical characteristics. That aspect of the matter is being dealt with separately, but it may be sufficient to state that a similar quantitative increase in strength at high temperatures is being obtained, in certain cases, as a result of similar modifications in composition.

In a consideration of this work it should be borne in mind that, apart from the simple metals, the materials selected for the research are representative of actual steels which have seen service conditions. By restricting the paper to these steels, the subject has been brought within its present compass. It will be realized that with so many elements to work upon the combinations are almost without limit, and it is the author's opinion that a proper appreciation of the possibilities of this field will enable the engineering world to develop successfully the various projects so dependent upon the satisfactory resistance of steel at high temperatures. Some of the steels dealt with in the paper are already complex in composition and constitution, but experiment may finally establish that the addition of cobalt, molybdenum, aluminum, and other elements may result in further advantages as regards the desirable characteristics.

In conclusion, the author would like to record his appreciation of the assistance rendered in the investigations by Mr. G. Stanfield, Mr. J. A. Clements, and other members of the Brown-Firth Research Laboratories staff. In particular would he like to express his thanks to his directors for permission to publish the results of the investigations. He would also like to thank Mr. C. C. Paterson of the General Electric Research Laboratories for the supply of pure tungsten used in the investigation.

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Otis to Install Continuous Sheet Mill

Installation of a new continuous sheet mill is planned by the Otis Steel Company when perfection of the much discussed process is completed, it was announced recently by E. J. Kulas, president of the Otis Steel Company, upon his departure for a brief European trip.

The company has a surplus of $2,000,000 in cash, with which to finance such a major improvement, Kulas said. During the two full years of the present management the sum of $7,334,375 has been expended by the company for maintenance, repairs, and improvements.

"At present a number of interests, both in the steel producing and steel mill equipment business, are endeavoring to perfect the continuous rolling mill process," said Kulas.. "If successful these efforts will mark the first important advance in sheet mill practice in many years. However, our engineers believe that many refinements are still necessary before the new development emerges assuredly from the experimental stage.

"Meanwhile, we are continuing our policy of manufacturing quality sheets at as low a cost as possible. In this effort we are receiving excellent co-operation form our labor, who have shown us various ways to keep down operating costs."

General Electric Builds Large Testing Pit

A pit which will permit the testing of the largest pieces of revolving machinery at runaway speeds with safety to the operators has just been completed at the Schenectady works of the General Electric Company. This pit, the largest of its kind ever constructed, will permit tests which cannot now be duplicated anywhere else in the world. It has been built for the purpose of running "double-speed tests" on the rotors of waterwheel generators, from the smallest size up to huge machines 40 ft. in diameter and weighing as much as 500 tons. The pit itself is a circular chamber with a depth of 30 ft., surrounded by two concentric walls of heavily reinforced concrete, between which there is a cushion of soft sand. Over the top is placed a cover 8 ft. thick, of reinforced concrete and steel plate, and around the rim two ring girders each 2½ ft. deep. The pit is housed in a large brick and steel building, placed in a field a quarter of a mile from the nearest factory building.

The Present Position of Low-Temperature Carbonization

By Major E. O. Henrici

The carbonization, or distillation, of coal at low temperatures is rousing considerable interest in many quarters, technical, financial, and political, but not all well informed, and there is some evidence of confusion in the minds of many speakers and writers as to what such processes can achieve and how near they are to achievement. There is more than one process of low-temperature carbonization, just as there are several high-temperature processes, and they have different objects. For example, the first, and essential, requirement of the gas industry is a sufficient supply of gas of suitable and uniform quality. Any coke, tar, or other by-products are useful as sources of income, but they are necessarily of secondary importance. Similarly, the first requirement of the coke-oven industry is the supply of coke suitable for metallurgical and other purposes; gas, tar, etc., are useful if they can be disposed of. The type of plant to be adopted depends in the first place on the primary product required and the nature of the coal to be used, and in the second place on the relative importance of the various by-products, which again depends on the markets locally available.

The primary object of low-temperature carbonization is not so clearly defined. One object, perhaps the most important from the national health point of view, is the production of a solid smokeless fuel suitable for use in the ordinary domestic grate, or cooking range, and in the smaller industrial furnaces. The general adoption of such a fuel would go a long way towards providing our cities with a purer atmosphere and abolishing what is generally referred to as the "smoke nuisance." If this object is to be achieved the coke produced must be in a suitable lump form, strong enough to stand transport, easily ignitable, and reasonably free from ash.

Such a fuel can be produced from suitable coal in retorts in which it lies quiescent during carbonization, such as the Parker retorts, or where it is only moved intermittently, as in the Fuel Research Station retorts. Any turning over, or considerable movement during carbonization, tends to form an undesirable amount of small coke. Experience at the Fuel Research Station indicates that any medium or strongly-caking coal can be used, or a blend of weakly and strongly-caking coals. It is found most satisfactory to charge the coal to the retorts in the form of nuts, with sizes below ⅜ in. screened out. Sizing the coal in this way increases both the throughput of the retort and the yield of tar. With a strongly-caking coal the resulting coke is in large lumps; with a weakly-caking coal the coke remains, generally speaking, in the same sized lumps as the coal charged. If large quantities of coal are to be treated with a view to supplying domestic fuel, it will be necessary to utilize the fine coal as well as the larger sizes. This can be done by briquetting before carbonizing, or in other ways.

A process such as that outlined above produces a considerable amount of rich gas, with a calorific value in the neighborhood of 1,000 Btu. per cu. ft., and full value for this can only be obtained if it be used for town's gas, in other words, if disposed of through a gas undertaking. In such a case it should be possible to credit the process with 3d. to 4d. a therm for the gas produced, whereas if the gas were used directly for heating the retorts, or under boilers, or for any other purpose where the high calorific value was of no particular advantage, the cash value of the gas would only be 1d. or 2d. a therm. For this reason it would appear that, generally speaking, the proper place for carbonizing coal when the coke is to be used for domestic purposes is at a gas works. This has the further advantage that a market for the coke is also available on the spot, with a selling agency in existence.

For these reasons the government asked Sir David Milne Watson, the Governor of the Gas Light & Coke Company, to go into the whole matter, and to say:

(a) Whether, in his opinion, any of these processes had reached such a point of development that it was worth while for his company to continue the experimental development on a large scale.

(b) If so, whether he considered the selected process or processes sufficiently promising to justify his company in taking the entire risk of this development.

(c) If not, whether he would submit a scheme, after discussion, whereby the government would be asked to bear a part of the risk involved.

The result of his report was that a subsidiary company (Fuel Production, Ltd.) has been formed, the capital of which has been guaranteed under the Trades Facilities Act, to erect a plant at the Richmond Gas Works with a capacity of 100 tons a day, and of the general design developed at the Fuel Research Station. This plant will be worked by the Gas Light & Coke Company, and the experience gained should show in the course of two or three years whether such a scheme will pay or not. Arrangements have been made by which all the experience gained will be freely at the disposal of any company desirous of taking up the process. Further particulars of the system, and of the arrangements made, will be found in the Annual Report of the Fuel Research Board for 1926, and in the report of a debate on Coal (Scientific Research) in the House of Commons on May 11, 1927.

Low Temperature Carbonization, Ltd., are also erecting a plant on the "Parker" system, and the results obtained will afford parallel experience.

It does not follow that processes producing domestic fuel should necessarily work in connection with a gas works. For example, the Maclaurin and the Midland Coal Products processes produce a lump coke, but as the retorts are internally heated by the combustion of a portion of the charge, the gas produced is large in volume and low in calorific value. It is not suited for general town supply, but only for heating retorts, boilers, furnaces, etc., or for use in internal-combustion engines, and then only when it can be used near the retorts where it is produced. Commercial plants on both these systems are in use, but both are finding a difficulty in obtaining a remunerative outlet for the gas. Neither process is suitable for carbonizing a strongly caking coal.

In some cases the primary object of low temperature carbonization may be the recovery of the oil-producing tars from the coal, the solid residue being used as an industrial fuel. In these cases the technical problem is in some respect simpler, as the coke need not be in lump form, nor is low ash content of such importance. It is thus possible to use a system in which the coal is turned over during carbonization, thus increasing the output by more rapid heating of the coal, and a lower grade coal can be used. On the

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other hand the coke will have a lower value than has domestic fuel. A process in which the coal is turned over during carbonization will also give as a rule a higher tar yield, and the tar may be less "cracked." Strongly-caking coals are not suitable for this type of retort. Many types of retorts, mostly on the rotary principle, have been proposed for such purposes, and these may be either internally or externally heated. Several large-scale plants are being erected in England and abroad to test the commercial feasibility of this type of process.

A plant which stands rather in a category by itself is that on the McEwen-Runge system, which is being tested at the Milwaukee power station. In this system the coal is pulverized and then carbonized in a current of hot gas, the tar is recovered, and the coke burned in the pulverized form in which it emerges from the retort.

In other cases, again, the primary object may be to produce a comparatively high-grade solid fuel from a low-grade raw material, with the recovery of such gas and tar as may be feasible. Such processes have the greatest promise of success where large quantities of low-grade fuel exist naturally, where they can be cheaply mined, as is the case with the brown coals in Germany, Canada, and Australia. They have also a a definite but somewhat limited application in England.

The most suitable site for the plant depends on the circumstances of each case. Where the coke is to be charged direct to furnaces there are advantages in having the plant close to the furnaces. Where a low-grade fuel is to be stepped up into a higher-grade solid fuel, a site near the colliery is indicated, but in all cases a suitable outlet for the gas is of importance, and in many cases the price obtained for the gas will decide whether or no the project is a financial success. It will be realized from what has been said that low-temperature carbonization processes are largely dependent for success on the degree to which they can combine with other industries so that all the products, solid, liquid and gaseous, can be used with advantage.

One great source of uncertainty in the financial outlook—and a financial profit is essential if any process is to be developed commercially—is the still unknown value of the tar. The tar is different both from high-temperature tar and from natural oils. Its properties have not yet been fully investigated, and their study forms the subject of most interesting research which is being actively pursued in several quarters, private and official, from various aspects. There is no doubt that these tars will yield fuel oil and motor spirit, but the best methods of treatment are not yet fully worked out. They will probably yield lubricating oils, and certainly various chemical products of use in the manufacture of disinfectants, preservative paints, and probably dyes and fine chemicals.

It is impossible in the space available to attempt to describe, or even to mention, the large number of different processes that have been tried or are being developed, but it can be said that over half a dozen different types of plant of a commercial size are, or are being, erected in various parts of the world, and the results obtained in the next few years should give information on various factors which are still unknown, such as the cost of working, the life of the retorts, and the prices to be obtained for the various products when these are available in considerable quantities. It is, unfortunately, still a fact that no process has yet proved that it can make a profit. It is to be hoped that this statement will no longer be true in the not too distant future.

—Chemistry and Industry.

Special Metallurgical Advisory Board Meeting

One year ago the Advisory Board, in co-operation with the U. S. Bureau of Mines and Carnegie Institute of Technology, began a study of the Physical Chemistry of Steel Making with particular reference to non-metallic inclusions in steel, fundamental reactions in steel manufacture, and the carburization of steel. On account of the complexity of the problem it was decided that the research should extend over a period of at least five years.

Twenty-six steel companies co-operated in the investigation during the past year. The research organization consists of six members of the technical staff of the Bureau of Mines, two research metallurists supported by the Advisory Board, six research fellows of the Carnegie Institute of Technology, and part time of three members of the staff of the institute.

The results of the past year's research are embodied in Bulletin 34 and in the fourth progress report, both of which will be presented at the next meeting. Bulletin 34 covers the solubility of iron oxide in iron over the temperature range 1,530 to 1,725 deg. C., the application of the results to steel manufacture, and some physical properties of the iron-oxygen alloys. The fourth progress report is concerned mainly with the formation and identification of iron silicates in steel, and with the formation and elimination of iron silicates in the basic open-hearth furnace.

The Advisory Board decided at its last meeting to invite the representative and the chief metallurgist of each co-operating company to attend the next meeting. At 4:00 P. M. on October 18, the visitors will meet at the Bureau of Mines, 4800 Forbes Street, for the purpose of inspecting the metallurgical laboratories where the major part of the research is being conducted. At 5:00 P. M. inspection will be made of the laboratories of the Department of Metallurgy and Bureau of Metallurgical Research at the institute. Dinner will be served at 6.00 P. M. at Carnegie Inn on the campus. The guest of honor will be Dr. John Johnston, director, Department of Research and Technology, United States Steel Corporation. Dr. C. H. Herty, Jr., head of the Ferrous Metallurgical Section of the United States Bureau of Mines will present a progress report on the co-operative research.

First Public Electric Power Plant

Forty-five years ago, on September 4, 1882, Thomas Alva Edison threw the switch which opened the first public electric light and power plant in the world, at 267 Pearl Street, New York, thus marking the beginning of the electrical industry which has grown since that time to such magnitude that it is capitalized in the United States alone at nearly 20 billion dollars, and its employees are numbered at more than one million men and women. In commemoration of the opening, Dr. John W. Lieb, who worked with Edison in designing and building the Pearl Street Station, placed a wreath on the tablet which marks its site.

The Maintenance of Motor Insulation*

Methods of Drying Out—Frequent Inspection of Insulation Necessary—Cleaning Should Be Carefully Performed—Treatment After Cleaning

By C. W. FALLS†

MOTORS should be stored in a dry, clean place until ready for installation. Heat should be supplied, especially for larger high-voltage machines, to protect against alternate freezing and thawing. This is equally applicable to spare coils.

Motors that have been long in transit in moist atmosphere, or have been idle for an extended period without heat to prevent the accumulation of moisture, should be thoroughly dried out before being placed in service. Machines may also become wet by accident, or they may "sweat" as a result of a difference in their temperature and that of the surrounding air, just as cold water pipes sweat in a warm, humid atmosphere. This condition is, of course, very injurious and should be prevented, particularly in the case of large or important motors, by keeping them slightly warm at all times. Current at a low voltage can be passed through the windings, electric heaters can be used, or even steam pipes may be utilized for protective purposes. In the case of extended idle periods, tarpaulins may be stretched over the motor and a small heater put inside to maintain the proper temperature.

Drying Out—If a motor has become wet from any cause whatever, it should be dried out thoroughly before being operated again. The most effective method is to pass current through the windings, using a voltage low enough to be safe for the winding in its moist condition. For 2,200-volt motors, 220 volts is usually satisfactory for circulating this drying-out current. Thermometers should be placed on the windings to see that they are being heated uniformly. Temperatures should not exceed 90 deg. C. (Class A insulation.) Applying the heat internally in this manner drives out all moisture, and is particularly effective on high-voltage motors, where the insulation is comparatively thick.

Heat may be applied externally by placing heating units around or in the machine, covering the whole with canvas or other covering, and leaving a hole at the top to permit the escape of moisture. In doing this, it is essential that there be a circulation of warm air over all the surfaces to be dried. The air should be allowed to escape as soon as it has absorbed moisture. Therefore, the heaters should be so placed and baffles so arranged as to get a natural draft; or small fans may be used to force circulation. Twelve-inch fans set to blow air across the fronts of "glow heaters" and then into the lower part of a machine from opposite sides, and so on up around the windings and out the top, will produce surprising results. The temperature of the winding should not be allowed to exceed 100 deg. C. for Class A insulated motors. Smaller machines may conveniently be placed in ovens, the same temperature limits being observed.

Insulation Resistance Tests—The time required for complete dry-out depends considerably on the size and voltage of the motor. Insulation resistance measurements should be taken at intervals of four or five hours until a fairly constant value is reached. This value should at least equal the recommended A.I.E.E. Standard, which is

$$\text{Megohms} = \frac{\text{Voltage}}{\text{Kv-a} + 1000}$$

The insulation resistance of dry motors in good condition is considerably higher than this value.

The more convenient way to measure this resistance is through the use of a "Megger," although if a 500-volt d.c. source is available, readings can be taken with a voltmeter. The ungrounded side of the system should be connected to all the motor terminals through the voltmeter, the opposite or grounded side being connected directly to the motor frame. The insulation resistance is found by

$$R = r\left(\frac{E}{V} - 1\right)$$

where R = insulation resistance in ohms
E = line voltage (d.c.)
V = voltmeter reading
r = resistance of voltmeter.

In using the voltmeter method the connection to the frame should always be made through a fuse of not more than 10 amperes in size. The circuit should be tested and the side showing a complete or partial ground then connected to the frame through the fuse.

Obviously the insulation resistance varies over a wide range, depending upon moisture, temperature, cleanliness, etc., but it is a good indication of the general condition of the insulation and its ability to stand the operating voltage. Such readings should be taken before a high-potential test, to determine whether the insulation is ready for such a test, and afterwards to make sure that the high potential has not injured the insulation.

High-potential Tests—High-potential test should be made after drying out, or after repairs, to determine the dielectric strength of the insulation. New windings should successfully stand a high-potential test of twice normal voltage plus 1000. There is some disagreement as to the proper value to use for motors that have been in operation for some time, but it is reasonable to assume that, after thorough cleaning and drying, the winding of a used motor should stand 150 per cent of normal voltage for one minute.

Small high-potential testing sets are available for such work and are of such capacity that very little damage will result from a breakdown during the test.

Periodic Inspection—A systematic and periodic inspection of motors is necessary to insure best operation, of course, some machines are installed where conditions are ideal, where dust, dirt, and moisture are

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*General Electric Review.
†Industrial Engineering Department, General Electric Co.

not present to an appreciable degree; but most motors are located where some sort of dirt accumulates in the windings, lowering the insulation resistance and cutting down creepage distances. Steel mill dusts are usually highly conductive, if not abrasive, and lessen creepage distances. Other rusts are highly abrasive and actually cut the insulation in being carried through by the ventilating air. Fine cast-iron dust quickly penetrates most insulating materials. Hence the desirability of cleaning the motors periodically. If conditions are extremely severe, open motors might require a certain amount of cleaning each day. For less severe conditions weekly inspection and partial cleaning is desirable. Most machines require a complete overhauling and thorough cleaning about once a year.

For the weekly cleaning the motor should be blown out, using moderate pressure, dry, compressed air (of about 25 to 30 lb. per sq. in. pressure). Where conducting and abrasive dusts are present, even lower pressure may be necessary, and suction is to be preferred, as damage can easily be caused by blowing the dust and metal chips into the insulation. On most d.c. motors and large a.c. motors the windings are usually fairly accessible, and the air can be properly directed to prevent such damage.

On the larger a.c. machines, the air ducts should be blown out so that the ventilating air can pass through as intended.

On large machines, insulation resistance readings should be taken in the manner indicated earlier in this article. As long as the readings are consistent the condition of the insulation would ordinarily be considered good. Low readings would indicate increased current leakage to ground, or to other conductors, owing to one of perhaps several causes, such as deteriorated insulation, moisture, dirty or corroded terminals, etc.

Cleaning—About one a year, or oftener if conditions warrant, motors should be overhauled. Smaller motors, the windings of which are not particularly accessible, should be taken apart.

First, the heavy dirt and grease should be removed with a heavy, stiff brush, wooden or fiber scrapers, and cloths. Rifle-cleaning bristle brushes can be used in the air ducts. Dry dust and dirt may be blown off, using dry compressed air of 25 to 30-lb. pressure, taking care to blow the dirt out from the winding. As stated before, if the dirt and dust is metallic, conducting, or abrasive, air pressure may drive the material into the insulation and damage it. Hence, for such conditions, pressure is not so satisfactory as a suction system. If compressed air at low pressure is used, care must be taken to properly direct it so that the dust will not cause damage and will not be pocketed in the various corners.

Grease, oil, and sticky dirt are easily removed by applying cleaning liquids like carbon tetrachloride (Pyrene, carbona), gasoline, or naphtha. All of these liquids evaporate quickly and, if not applied too generously, will not soak or injure the insulation. Carbon tetrachloride is best and is recommended because it is non-inflammable.

In case one of the other liquids must be used, it should be applied out of doors or in a well-ventilated room. It must be remembered that gasoline or naphtha vapor is heavier than air and will flow into pits, basements, etc., and may remain there for hours or even days. The casual smoker, a spark from a hammer or chisel, or even from a shoe nail may cause a serious explosion. Therefore, proper ventilation of the room is essential and may require specially piped ventilating fans. In using carbon tetrachloride the explosion hazard is eliminated, but some ventilation is required to remove the vapor, which might affect the safety and comfort of the workmen.

There are several good methods of applying the cleansing liquid. A cloth, saturated in the liquid, may be used to wipe the coils. A paint brush, dipped in carbon tetrachloride, is handy to get into corners and crevices, and between small coils. Care should be taken not to soak the insulation as would be the case if coils or small machines were dipped into the liquid.

Probably the best method of applying the liquid is to spray it on. A spray gun, paint spraying appliance, or an ordinary blow torch are often used with good results, although the latter device is apt to give a heavier spray than desirable.

An atomizer will give excellent results, using a pressure of about 80 lb. if the insulation is in good condition, or 40 to 50 lb. if the insulation is old. The atomizer should be held not more than 5 or 6 inches away from the coils.

While the insulation will dry quickly at ordinary room temperature after such cleaning methods, it is highly desirable to heat it to drive off all moisture before applying varnish. This heating or drying-out process has already been discussed and, therefore, need only be mentioned here.

If the motor can be spared from service long enough, the insulation should be dried out by heating to from 90 to 100 deg. C. While warm, a high-grade insulating varnish should be applied.

The varnish may be sprayed or brushed on. For small stators or rotors, it is best to dip the windings into the varnish, cleaning off the adjacent metal parts afterwards by using a solvent of the varnish. After applying the varnish, the best results are obtained by baking for 6 to 7 hours at about 100 deg. C. Experience with particular conditions of operation, or the condition of the insulation, may indicate the desirability of applying a second coat of the same varnish, followed again by 6 to 7 hours of baking at 100 deg. C.

If the machine must be put back in service quickly, or if facilities are not available for baking, fairly good results will be obtained by applying one of the quick-drying black or clear varnishes which dry in a few hours at ordinary room temperatures.

Testing—Insulation resistance readings should be taken, as explained previously, to determine whether the winding is in satisfactory condition for applying a high potential test. After this test, it is good practice to run the motor without load for a short time, to make certain that everything has been connected, assembled, and adjusted properly.

Additional Information to Contribution in September Issue

Under the title Wheeling Steel Corporation's New Skelp Mill, in the September issue of The Blast Furnace and Steel Plant mention should have been made that the Westinghouse Electric & Mfg. Company developed special motors and control to operate the Mesta patented electric flying shear installed with the continuous mill.

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The POWER PLANT

Feedwater Problems, and Treatment*

A Survey of Methods for Removing Suspended Solids and Non-Condensable Gases and for Eliminating Scale Forming Salts. Priming and Foaming Briefly Discussed

By SHEPPARD T. POWELL†

GREATER economy in the design and operation of steam-generating equipment has been in the past and still is the impelling motive responsible for the rapid improvement that has taken place in the field of steam engineering within recent years. The condition has been especially pronounced during the past 20 years, and it is indicated that even greater activities along these lines are to be anticipated in the immediate future. Radical changes in boiler and furnace design, higher steam pressures and temperatures, and improvement in the design of prime movers have focused attention upon feedwater treatment. As a result of these conditions, a properly designed feedwater make-up system is now recognized generally as a necessary and important factor in steam generation.

Good water is a relative term and may not be easily defined. Water of satisfactory quality for one purpose may be entirely unsuitable for a dissimilar service. This holds true not only for water employed in the various industries, but when it is to be used for boiler feedwater. An ideal water for steam generation should contain no scale-forming solids, should not cause priming or foaming, and should be non-corrosive. Such supplies are seldom, if ever, obtainable from natural sources. The degree of purification desired depends entirely upon operating conditions. This resolves itself into an economic balance between the cost of treatment and the ultimate return on the investment resulting therefrom.

The primary object of feedwater purification outside of the boiler is twofold, namely:

1—Removal of suspended and soluble solids.
2—Removal of gases.

There are numerous other incidental advantages to be gained from such systems, but the major one may be classified under one of these groups. There are, in addition, many kinds of so-called internal treatment, intended to inhibit scale formation and corrosion. Numerous appliances are available that may accomplish these results more or less efficiently. The engineer is faced with the difficult task of determining not only the relative values of these systems, but their specific adaptability under a given set of operating conditions. Lack of fundamental knowledge concerning the functioning of the various systems results, frequently, in the installation of ill-advised treatment plants. It is the purpose of the author merely to indicate the general adaptability of the more important methods of treatment without attempting to designate the type of system for a specific set of conditions.

Removal of Suspended Solids

The oldest and cheapest means of removing suspended solids from water is by plain subsidence. Clarification of muddy water by this method was practiced by the ancient races, and it is still employed widely for this purpose. Plain subsidence should not be considered as a complete feedwater purification system. It has, however, a definite place as an adjunct to feedwater treatment, where the raw water contains a large amount of suspended solids. It is possible, frequently, to effect considerable economy in the operation of chemical softening plants, filters, or evaporators by removing the gross amount of suspended matter by plain sedimentation prior to purification by more elaborate treatment.

The efficiency of subsidence basins depends largely upon the care exercised in their design. The inlet and effluent weirs, the placing of baffles, the designed rates of flow, and many other factors should be considered. The final decision as to use of primary subsidence basins rests upon the unit cost of removal of the settleable solids by this method in comparison with other processes that effect comparable results.

Considerable interest has been taken recently in mechanical thickeners and clarifiers for the removal of settleable solids from feedwater. These appliances are tanks so designed, as to direct by mechanical means the settled solids to one portion of the equipment from which they may be removed continuously or intermittently. The value of these appliances consists in using relatively shallow tanks requiring no appreciable storage capacity in the tank. Tanks of this kind are now being used as subsidence basins, either as plain settling basins, or for coagulation and settling by means of chemicals. They are employed also in cold lime-soda for removal of lime sludges. In many instances they are particularly well suited for this kind of service. The Dorr, Hardinge, and Booth clarifiers are types of equipment that have been adapted to this service.

Filters

Sand filters are used extensively for the elimination of suspended solids either from turbid surface waters or solids carried over from the reaction tanks from chemical softeners. Pressure filters are most commonly employed, although in some large installations gravity filters are in use. Filter design has been fairly well standardized at the present time, and outside of minor specific appurtenances there have been few radical changes in this respect. The most important change in the design of pressure filters recently has been the strainerless filter equipped with a single control valve. This filter is novel, since it contains no strainers or sand valves and the shape of the shell is conical instead of cylindrical.

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*Presented at Regional Meeting of A.S.M.E., Kansas City, April 4, 1927.

†Chemical engineer, Baltimore, Md.

Chemical Softening

The removal of scale-forming solids from feedwater by means of chemicals has been practiced for many years. The basic principle of this process is relatively simple and is generally well known. It consists of the addition of chemicals to the water to convert the soluble scale-forming salts into insoluble compounds and removing these solids by settling or filtration. Lime and soda, or lime and barium, are generally employed in this country. These processes are fairly well standardized, and the only recent important development other than changes in mechanical equipment is the use of the sodium aluminate reduces the cost of treatment. ing reagents. It has been demonstrated that with many waters sodium aluminate in small doses may effect a much larger residual hardness in the treated water than can be obtained by straight lime-soda or lime barium treatment. In some instances the addition of the sodium aluminate reduces the cost of treatment. The process is coming into general use in the treatment of feedwater for locomotives, and many industrial plants have adopted it for softening for industrial or boiler-feed use.

At a few plants preliminary softening by chemicals is followed by zeolite softening. The purpose of these combination systems is the removal of the gross amount of scale-forming solids by the lime-soda or lime-barium and removal of the remainder of the lime and magensium salts by the zeolite material.

It is frequently more economical to produce satisfactory results in this way than by either method alone. Where such treatment is employed, the preliminary treatment must be carried on in cold water since zeolite softeners do not function satisfactorily with hot water.

Zeolite Water Softeners

Zeolite water softening has been employed widely in the past for the treatment of water used in a number of industries. This form of treatment is now employed for softening many feedwater supplies. The system is relatively simple, consisting of passing the water through a bed of zeolite mineral that extracts the scale-forming solids from the water and replaces these sodium salts. Since the latter compounds do not form scale, this system is particularly well suited for the treatment of some waters.

After a given amount of sodium is exhausted from the mineral bed and replaced with calcium or magnesium from the water, the unit is cut out of service and the exhausted sodium replaced by sodium chloride (common salt) solution. When the mineral has been regenerated, the excess salt is removed by washing the bed with fresh water and the softener is again ready for service. Zeolite softeners are of practically the same design as pressure filters, in which the filter medium is replaced by the zeolite mineral.

This method of treatment is not suited to all waters. Since all lime and magnesium salts are replaced by sodium, the treatment of very hard waters by these softeners will result in high concentrations of sodium in the softened water. The cost of operation may also be excessive in comparison with other forms of treatment. In most instances the water must be filtered prior to the passage through the zeolite bed, since suspended matter rapidly coats over the grains of the softening mineral, thereby reducing their softening action. In case the raw water is acid, the acidity should be neutralized before attempting to soften the water by zeolite. Water high in iron, free CO_2, or manganese may require preliminary treatment.

Zeolite-softened waters, due to the relatively high concentration of sodium salt, have been held responsible in some cases for the embrittlement of boiler metal. This, however, is still a debatable hypothesis which is not conceded by all engineers. This form of feedwater treatment has a particular sphere of usefulness, and when so applied and properly operated should give satisfactory service. Zeolite softeners are being used to some extent in combination with chemical softeners. A few installations have also been made where the water fed to evaporators is first softened to remove the scale-forming solids. The only value of combination treatment of this kind is in the possible economy to be effected. Removal of the scale-forming solids from the water passing into an evaporator permits better heat transfer by the evaporation coil and may reduce cracking-down periods. Such systems are only warranted under unusual conditions where economy of operation can be demonstrated.

Evaporators

In modern high-pressure plants, the feedwater should be as free from all solids as is practically possible. This is fairly well recognized and the majority of the larger stations and many small ones built recently have made provision to treat the feedwater make-up by the use of evaporators. Theoretically water from evaporators should contain no soluble or suspended solids. This condition is seldom obtained, however, in practice. Distillate from evaporators will contain usually from one-quarter to one grain per gallon of solids. Considering, however, that the percentage of make-up is usually from 2 to 4 per cent of the total feedwater, no difficulty from scale-forming solids from this source is probable. From an economic viewpoint, it is difficult to warrant the use of evaporators where the percentage of make-up is in excess of 20 per cent of the total volume of feedwater.

Evaporators may be either high or low-pressure or may be single-effect or multiple-effect units. The choice of the type of evaporator to be used should rest entirely upon the heat balance of the station and the ultimate economy that may result from the installation. These facts may be determined only as the result of a comprehensive engineering study of station conditions. The factors to be considered in an investigation of this kind should include:

1—The maximum percentage of make-up water

2—The nature of the raw water

3—The feedwater-heating equipment

4—The estimated condenser leakage and the nature of the impurities that may be carried into the make-up from this source

5—The maximum, minimum, and average load on the station

6—The source or sources of exhaust steam other than from prime movers

7—The relative cost of installation and operation in comparison with other feedwater-purification equipment.

There are numerous other incidental items that will be apparent in specific instances.

Aside from all other considerations, there is a definite trend toward the employment of evaporators to furnish make-up water to all high-pressure boilers. It is difficult to predict what the chemical reaction of solids in water may result at extremely high temperatures and pressures. For this reason the necessity for make-up water containing as little solids as possible is recognized. As has been stated, an intelligent decision as to the installation of this type of feedwater treatment may be made only as a result of careful study of local conditions.

Deaerators

Experience in steam engineering has demonstrated the importance of complete deaeration of feedwater. The removal of non-condensable gases from feedwater is now considered a necessary precaution to inhibit corrosion of boilers and appurtenances and to insure efficient surface-condenser operations. It is a well-known fact that oxygen and carbon-dioxide gas, two gases generally present in all natural waters, are active accelerating agents of corrosion. Where the feedwater make-up carries scale-forming solids, the tubes and sheet of boiler are protected from the corrosive action of these gases. When the incrustants are removed from the water by external treatment, the metal may be entirely free from scale. Under these conditions, oxygen and other non-condensable gases coming into direct contact with the metal set up an active corrosion. To inhibit this action, it is essential completely to deaerate the feedwater before it enters the system. Open feedwater heaters and chemical treatment of the feedwater that is carried out in hot solution effect a fairly high removal of these gases. Dissolved gases are not completely removed, however, by these appliances, so that in many steam plants it has been found necessary to install deaerators or deaerating heaters. By these apparatus practically complete removal of gases can be obtained.

In addition to the corrosion that may result in economizers and boilers from non-condensable gases in the feedwater, other operating difficulties can be traced to this source. The corrosion of superheater tubes and steam lines is frequently traceable to this source. Non-condensable gases are responsible also at times for poor condenser performance due to the blanketing of the tubes, thereby, resulting in poor heat transfer. Removal of gases carried over to the condenser from the boiler imposes frequently heavy duty upon the air-ejector equipment. These factors are of importance in considering the economic balance and the financial returns chargeable to the deaerating system.

Continuous Blow-Down Systems

In an effort to achieve greater economy of boiler operation, attention has been directed lately to continuous blow-down schemes. Blowing down of boilers to inhibit too high concentration of soluble and suspended solids is a necessary operation, but entails losses that in a large plant may be relatively great in a year's time. The major loss is due to the heat in the blow-down water discharged to the sewer. The value of the water blown down, the wear on the valves, and other incidental losses are also important factors to be considered.

A number of appliances for the purpose of reducing these losses have been placed upon the market within the past two or three years. Some of these schemes are ingenious, and when properly applied are warranted. Other appliances designed for this kind of service have little real merit. One type of continuous blow-down is essentially a small pressure filter, through which the blow-down water is filtered and returned to the boiler without appreciable loss of heat. The equipment removes the suspended solids and the clarified blow-down water with the soluble solids is returned to the boiler. The value of the system is the saving effected by removing the suspended solids thrown out of solution in the boiler and the removal of these constituents without loss of heat.

There are at least two continuous blow-down systems that are designed to utilize the heat released from the blow-downs to heat the feedwater in specially designed heat exchangers. In one of these schemes, a two-pass heat exchanger is used. The cold raw water enters the unit on its way to the heater and the discharge from the heater then flows through the first pass on its way to the boiler.

Much more elaborate blow-down systems are being utilized in Europe, and one of these systems is now being offered to the American trade. In these systems the blow-down water is used to heat the raw water in hot chemical softeners. By this scheme the solids discharged from the boilers are said to aid in softening, and less live or exhaust steam is required to bring the water up to the desired temperature.

Continuous blow-down systems have merit, and, when properly designed and operated, can produce sufficient economy of operation to warrant their installation. As an adjunct to other methods of feedwater treatment, it is indicated from the data now available that these appliances have a specific sphere of usefulness.

Electrolytic Scale-Prevention Appliances

Much has appeared in the technical press recently concerning electrolytic processes for the inhibition of scale and corrosion in boilers, condensers, and heaters. Up to the present time, six systems of this kind have come to the author's attention. A number of these installations have been made in this country and abroad. No uniformity of opinion exists among investigators as to the value of these appliances. In some instances good results were obtained, while others have reported that the value of the process was doubtful. In one or two cases it has been stated that corrosion was accelerated.

A rather extensive investigation has just been completed at one of the large public utilities in this country. An experimental boiler was constructed and operated under the joint supervision of the manufacturer and the company. The results of this test have not yet been made public. It was learned from a private communication, however, that the system completely stopped all scale formation in the drum of the boiler but the tubes scaled up rapidly. The same type of system has proved satisfactory, however, in inhibiting corrosion in open heaters. A number of electrolytic processes are being tested on locomotives, but definite conclusions as to the merit of these systems have not yet been obtained.

Internal Treatment

This form of boiler-water treatment has been employed from the earliest use of steam boilers. Under this heading is to be classed the great variety of boiler compounds and the numerous types of treatment employing sodium salts. In the majority of instances, external treatment of feedwater is preferrable to the use of compounds. There are cases, however, where the direct application of chemical to boiler water is warranted. When this form of treatment is intelligently controlled, relatively good results are possible. The principal objection to the use of compounds is the indiscriminate use of materials of unknown composition. Many of these products are useless and may result in serious operating difficulties.

A number of scientific investigations have been carried on to determine the specific value of sodium compounds and similar materials for the inhibition of scale formation and corrosion. These data have demonstrated the specific value of such treatment and its limitations. Many products have been placed upon the market recently that have some value in preventing the formation of hard scale. These substances are mostly organic products that inhibit the adherence of scale-forming solids, maintaining these salts in the form of sludge. Colloidal compounds are to be classed in this group. Sodium aluminate has recently been applied successfully in a number of installations.

Problems are encountered in steam generation that in a strict interpretation may not constitute feedwater treatment. Many of these difficulties are closely allied with the compostion of the make-up water, however, and may not logically be divorced from the subject. The more important operating difficulties are priming and foaming, embrittlement of boiler metal, and various forms of corrosion. Equipment designed for controlling these factors or methods of operation devised to inhibit such action should therefore be placed under the general classification of feedwater treatment.

Priming and Foaming

This phenomenon is familiar to all operating engineers. It is surprising, however, to find how little definite knowledge is available concerning the actual conditions responsible for these troubles. It is believed generally that sodium salts are responsible for all priming and foaming. These salts and other soluble compounds are undoubtedly contributing factors. Recent experimental investigations, however, have demonstrated that many other factors are of importance and may not be ignored. The nature and degree of fineness of the suspended solids, and many other items enter into the problem.

In addition to the chemical and physical qualities of the feedwater there are numerous structural and operating details that are responsible in part for the priming and foaming of boiler waters. Treatment of the feedwater may inhibit the tendency toward priming and foaming or may increase this action. Removal of suspended solids improves conditions and increasing soluble salts, particularly sodium compounds, under some conditions, accelerates the phenomenon.

It is common practice to blow down boilers at intervals to maintain a concentration in the boiler sufficiently low so as to minimize the amount of moisture carried from the boiler. This is a relatively costly operation and frequently results in an appreciable financial loss in a short time. It is necessary in most cases to blow down boilers, but a careful study of conditions and proper treatment of the feedwater may reduce greatly the quantity of water blown down.

Steam purifiers are coming into use rapidly. The purpose of these appliances is to remove the moisture and solids from steam by mechanical means. There are several manufacturers of this kind of equipment. In many cases the installation of steam purifiers is warranted, since the saving resulting from dry steam free from impurities eliminates many heavy losses throughout the steam cycle. These appurtenances may not be considered "cure-alls" but when employed in conjunction with proper feedwater conditioning are of specifiic value.

Corrosion of boilers and of similar equipment and to a lesser degree the embrittlement of boiler metal, are definite problems that cause much annoyance in some stations. These operating difficulties are complicated, involving not only the feedwater but numerous other factors. To what extent the feedwater is responsible is not always apparent. Where such troubles are encountered, a careful investigation of all conditions should be made since a solution may be obtained only in this way.

Corrosion of boilers and appurtenances is often the result of improper feedwater treatment or failure to provide any form of treatment. The most important single factor accelerating corrosion is oxygen. The removal of oxygen from feedwater may not completely inhibit corrosion, since other constituents in water are contributory agents. The removal of oxygen will reduce merely the rate of corrosion in proportion to its specific effect.

Boiler Feedwater Studies Committee

Recently, the importance of boiler-feedwater purification has focused the attention of many individuals and groups of engineers upon this important subject. There has developed an insistent demand for fundamental information of the chemistry of water as related to feedwater problems. As a result of this need, a comprehensive study of this subject was undertaken about three years ago by a group of engineers and chemists interested in these various problems. The movement has been expanded until at the present time it is sponsored, as a joint study, by six of the major engineering organizations interested directly or indirectly in the various phases of this work.

Horace A. Beale Dead

Horace A. Beale, Jr., president of the Parkesburg Iron Company, Parkesburg, Pa., died on September 6, aged 57 years. He was born at Hibernia, Pa., where his father, Horace A. Beale, who for years was a prominent iron master, operated the Hibernia Iron Works before moving to Parkesburg in 1872. Mr. Beale began work with the Pennsylvania Steel Company, Steelton, Pa., in 1892, and in 1893 came to the Parkesburg Iron Company, where, after thoroughly learning the manufacture of charcoal iron, he became vice president in 1898 and president in 1900.

During his administration of the Parkesburg Iron Company, a tube mill, for manufacturing charcoal iron into boiler tubes, was built in 1908.

Tentative Program, First National Fuels Meeting

St. Louis, Mo., October 10-13, 1927

MONDAY, OCTOBER 10

Morning

9:00—Local Sections, Fuels Conference.
9:30—Registration.
11:00—"Address on Fuels," S. W. Parr, Professor of Applied Chemistry, University of Illinois, Urbana, Ill.

Afternoon

2:00—General Session:
"American Fuels Resources," O. P. Hood, Chief Engineer, U. S. Bureau of Mines, Washington, D. C.
"Combustion and Heat Transfer," Prof. R. T. Haslam and H. C. Hottel, Massachusetts Institute of Technology, Cambridge, Mass.
"Recent Developments in Low Temperature Coal Carbonization," H. D. Savage, Vice President, Combustion Engineering Corp., New York, N. Y.

Evening

Smoker and Ladies reception.

TUESDAY, OCTOBER 11

Morning

9:30—Industrial Session:
"The High Cost of Fuel Saving," W. Trinks, Professor of Mechanical Engineering, Carnegie Institute of Technology, Pittsburgh, Pa.
"The Relative Values of Gaseous, Liquid and Solid Fuels," F. J. Ward, Professor, Fuels and Gas Engineering, Massachusetts Institute of Technology.
"Application of Powdered Fuel to Smaller Boiler and Industrial Installations," H. Kreisinger and A. B. Wolle, Combustion Engineering Corporation, New York, N. Y.

Power Plant Session:
"Characteristics of Modern Boilers," E. R. Fish, Vice President, Heine Boiler Company, St. Louis, Mo.
"Direct Fired Powdered Fuel Boilers with Well Type Furnaces at Charles R. Huntley Station," H. M. Cushing, Chief Engineer, Buffalo General Electric Company, Buffalo, N. Y.

Afternoon

2:00—General Session:
"The Clinkering of Coal Ash as Related to Laboratory Fusibility Determinations," A. C. Fieldner, W. A. Selvig and P. Nicholls, U. S. Bureau of Mines Experiment Station, Pittsburgh, Pa.
"Factors Governing the Purchase of Fuels," Morgan B. Smith, Engineer, General Motors Corp., Detroit, Mich.
"Refractories for High Temperatures," Stewart Phelps, Director of Research and Tests, American Refractories Institute Fellowship, Mellon Institute, Pittsburgh, Pa.

Evening

Banquet and Mass Meeting. (Engineers and Smoke Abatement League.)

WEDNESDAY, OCTOBER 12

Morning

9:30—Industrial Session:
"Progress in Gas-Producer Practice," W. B. Chapman, Vice President, Chapman Engineering Company, New York, N. Y.
"The Use of Fuels in Brick Kilns," W. E. Rice, Assistant Fuel Engineer, U. S. Bureau of Mines, Pittsburgh, Pa.
"The Burning of Liquid Fuels," Ernest H. Peabody, President, Peabody Engineering Corp., New York, N. Y.

Power Plant Session:
"Characteristics of Modern Stokers," F. H. Daniels, President, Riley Stoker Company, Worcester, Mass.
"Air Preheaters," Frank M. Van Deventer, Special Engineer, Henry L. Doherty Company, New York, N. Y.
"Automatic Combustion Control," T. A. Peebles, Chief Engineer, Hagan Corp., Pittsburgh, Pa.

Afternoon

2:00—General Session:
"Coal Mining and Coal Preparation from Standpoint of Quality," Wm. Beury, General Superintendent, Algoma Coal & Coke Company, Algoma, W. Va.
"Some Interesting Phases of Dry Quenching Coke," A. M. Beebee, Superintendent, Gas Manufacturing Department, Rochester Gas & Electric Corp.
"Smoke Prevention in Railways," J. B. Irwin, Chief Smoke Inspector, Chicago & Northwestern Railway.

THURSDAY, OCTOBER 13

Morning

9:30—Smoke Abatement Session:
"The Measurement of Atmospheric Smoke Pollution Visible and Invisible," Dr. George T. Moore, Director, Missouri Botanical Garden, St. Louis, Mo.
"Smoke Abatement Methods Used in Cleveland," Col. Elliott H. Whitlock, Commissioner of Smoke Inspection, Cleveland, Ohio.
"Managing a Smoke Abatement Campaign," Erle Ormsby, President, Citizens' Smoke Abatement League, St. Louis, Mo.

Afternoon

2:00—Smoke Abatement Session:
"Furnace Essentials for Smokelessness," H. B. Meller, Chief, Bureau of Smoke Regulation, Pittsburgh, Pa.
"Smokeless and Efficient Firing of Domestic Furnaces," Victor J. Azbe, Consulting Engineer, St. Louis, Mo.
"The Effect of Atmospheric Smoke Pollution—A summary of opinions from Current Literature," Prof. A. S. Langsdorf, Director of Industrial and Engineering Research, Washington University, St. Louis, Mo.

Operation Problems Encountered in Boiler Operation at Omaha

By Charles F. Turner*

In the Omaha station of the Nebraska Power Company, there are three 1,500-hp. B. & W. cross-drum boilers and one 2,000-hp. B. & W. cross-drum boiler. Each boiler is equipped with a Coxe chain-grate stoker, a Foster side-wall radiant superheater, and a Duratex counterflow economizer.

Fuel used in this plant is bituminous slack from Illinois, west Kentucky, and Kansas. Two characteristics of certain grades of Kansas coal are low ash content and clinkering quality of the ash. The clinkers form on the grate in a molten mass and cling with such tenacity that it became necessary to construct a scraper at the ashpit. This scraper is made of slabs of cast iron about 12 in. by 18 in. by ½ in., each slab being hinged on a common support rod. The supporting rod is in turn fastened beneath the return shaft at the edge of the ashpit, and the scrapers drag the clinkers from the grate into the ash hopper.

Stoker Drives

Each boiler is served by two grates and consequently has two stoker drives. Stokers are driven by d.c. motors, and one of the first experiences showed the necessity of an auxiliary drive to serve in an emergency. For this purpose two a.c. motors are mounted on low trucks, to facilitate moving, and one of these motors can be wheeled into place, bolted to the floor, and put in operation in less than two minutes.

Economizers

Our first difficulty with ecenomizers came after six months' service when we found internal pitting progressing at an alarming rate. Increasing the feedwater temperature from 180 to 210 deg. F. decreased the corrosion to a minimum by driving off the dissolved oxygen.

Cleaning the outside surface of the tubes presented the next problem. The steam pressure on the soot blowers at the time was 200 lb. and did not thoroughly clean the tubes. Washing with water at intervals of two weeks cleaned the surface down to the bare steel. When washing an economizer, the boiler must be operating at high rating and the fans stopped. After washing thoroughly the boiler is brought to high rating again and thus the economizer is quickly dried out.

During 1925 and 1926 the steam pressure was raised from 200 to 325 lbs., and it was discovered that the economizers did not get dirty as heretofore due to the higher pressure on the soot blowers.

Some trouble was experienced on one economizer when a tube roll started a small leak. This leak could not be detected from the outside, and as a result a nest of 13 tubes corroded so badly in this spot as to cause their removal. We believe more adequate provision should be made for inspecting the ends of tubes next to the header boxes, and we are considering placing doors to accomplish this, up and down the ends of the economizer.

In January of this year a general clean-up and overhaul of the economizers disclosed excessive pitting around handhole caps and boxes, due to seepage of water through gaskets, with the resulting formation of acid when soot and water come in contact. Headers and caps have now been painted with graphite and boiled linseed oil to prevent this corrosion.

Slagging

In operating these boilers at from 200 to 300 per cent of rating we found it impossible to maintain mechanical soot blowers in the lower part of the first pass. At the same time this is a vital part of the tube surface, and with high ratings the slag forms on the lower or drop tubes quite rapidly. Therefore a steam hand lance was used to supplement the work of the mechanical blowers. But a steam hose, whether metal or rubber, is a hot, dangerous tool at best, and with the pressure at 300 lbs. the danger is increased proportionately. We decided to try water, and after some experimenting found that city water at 100 lb. pressure when forced through a nozzle having a diameter of 5/32 in. would do the work almost as fast and certainly cleaner than steam at 300 lbs. Also with a smooth, straight nozzle 3 in. long it is possible to clean slag from a tube 15 to 20 ft. from the end of the 4-ft. lance.

The side-wall radiant superheaters were equipped with special soot blowers, but these soon burned off and we have been very successful in using a lance made of ½-in. pipe having a nozzle at the end drawn down to about 3/16 in. diameter. In this lance we use compressed air at 100 lb. pressure, and by entering it through a narrow door in the back wall close to the superheater surface we are able to blow all slag from the exposed surface in a very few minutes.

Sizing and Tempering Coal

There are two more items that may be of interest to some operators in regard to preparation of coal for burning. First, all coal is tempered before being run through the crusher, and is then crushed to such size as to pass through a ½-in. screen. In the tempering it is our experience that when the crushed coal can be molded in the hand without making the hand wet, the moisture content is just right to give an even air distribution and thus obtain best results in the furnace. It may be interesting to some to know that after repeated tests we have found that 14 per cent total moisture gives the desired condition. In other words, if a coal has 8 per cent moisture we must add 6 per cent in order to get the right consistency, but if it has 12 per cent moisture, we need add only 2 per cent.

—Mechanical Engineering.

Power Show

The scope, size and consequent importance of the New York Power Show to be held from December 5 to 10 compels the attendance of every American manufacturer with his technical staff to glean from this comprehensive mechanical exhibition the kernels of information that will save him many dollars in operating expense.

Every American manufacturer faces a daily crisis —the one demanding increased production and decreased costs. Through this critical situation he relies on the development of new machines and new methods for the saving of time, effort and money. American industry is on its mettle today as never before and its leaders are availing themselves of every scrap of information about new mechanical equipment that can be put to work in any corner of the factory. The manufacturers of the United States have been uniformly successful in meeting rapidly changing conditions. New equipment and methods are scrapped freely if a replacement offers increased production or reduced cost.

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*Chief Operating Engineer, Nebraska Power Company, Omaha, Neb.

The coming Power show is the sixth of the series and promises the greatest success, which is easy to understand in a country which puts such a premium on novelty and improvement. But the coming event is of greater importance than its predecessors for this exposition gives under one roof an unsurpassed opportunity to study all the types of mechanical equipment that American manufacturing may use to advantage. Over 500 concerns will be represented and their showings will include those of machinery for power generation, heating and ventilating, refrigerating for large industries and office buildings. There will be many displays for measuring and recording time, pressure and volume. There will also be outstanding examples of modern machine shop equipment, material and woodworking machines and an especially noteworthy collection of exhibits of power transmission equipment.

With this splendid collection of devices of all kinds the manufacturer will find sufficient to keep him and his technical staff busy for several days analyzing with a view to adopting devices to his own plant and his own conditions. If he is a manufacturer of shoes or typewriters and his power costs are not a large percentage of his manufacturing cost he will still find a tremendous amount of valuable assistance in the exposition. He may be able to revise his entire manufacturing process by a study of the material handling equipment that will be shown, by a choice of some new types of hangers he may be able to reduce the maintenance of his shafting 50 per cent, by the adoption of a new metal or woodworking machine to his shipping or packing he may save 10 to 15 per cent of his costs. All of these opportunities are available to men in every industry who will undoubtedly use them during the week of December 5 to 10 when the National Exposition of Power and Mechanical Engineering will be held in the Grand Central Palace, New York.

Consumption of Fuels by Public-Utility Power Plants

The total amount of electricity produced at public-utility power plants in 1926 was 73,791,000 kw-hrs., according to a statement just made public by the Geological Survey of the Department of the Interior. Of this total, 47.5 billion kw.-hrs., or 64.5 per cent, was generated by the use of fuels and the remainder by the use of water power. Of the 47.5 billion kw.-hrs. produced by the use of fuels, 42.6 billion, or 90 per cent, was generated by the use of coal alone; the remaining 10 per cent of fuel-power output was generated by the use of fuel oil, gas, and wood. Coal is thus by far the chief source of power generated at public-utility power plants. In 1926 the power produced from coal was 57.7 per cent of all the power generated, from water power 35.5 per cent, from oil 3.1 per cent, from gas 3.3 per cent, and from wood 0.4 per cent. The use of fuel oil in generating electricity has declined since 1924, when it reached its maximum, and less fuel oil was used in 1926 for this purpose than in any other year since 1918. Indeed, in 1926 the amount of fuel oil consumed by public-utility power plants was only 57 per cent of that used in 1924.

The average rates of consumption of the different kinds of fuel in generating electricity in the United States were as follows: Coal, 1.94 lbs. per kw.-hr.; oil, 243 kw.-hrs. per barrel; gas, 22 cu. ft. per kw.-hr. The best fuel rates for these different fuels were about as follows: Coal, 0.9 lb. per kw.-hr.; oil, 450 kw.-hrs. per barrel; gas, 13 cu. ft. per kw.-hr. As these are roughly one-half the average rates, the consumption of fuel by electric public-utility power plants would be reduced one-half if all public-utility power plants produced electricity at the best fuel rates, and the attainment of this degree of efficiency would have conserved more than 20,000,000 tons of coal in 1926, representing a value of about $75,000,000.

Contract for Ten Billion Feet of Gas

A revolutionary industrial step is reflected in the announcement of the signing of a contract by the Public Service Corporation of New Jersey for the purchase of a minimum of ten billion feet of gas during the next 10 years from International Combustion Engineering Corporation's new low temperature coal carbonization plant to be erected at New Brunswick, N. J.

This plant is the first of International Combustion Engineering Corporation's construction of the kind in this country, the process having been in successful commercial operation for several years at Essen, Germany, where thousands of tons of coal have been distilled and the products marketed. This plant will handle approximately 250,000 tons of bituminous slack coal per year through the initial installation of the eight units. In addition to the gas which is a by-product the plant will produce six million gallons per year of coal tar, which has all been contracted for by the F. J. Lewis Manufacturing Company of Chicago; 1,250,000 gal. of crude motor spirits, which is said to be higher in power than the present blended gasoline.

There will also be produced from the coal tar of this plant 2,750,000 gal. per year of the heavier distillates which will find their way into the business of wood preservatives, the manufacture of disinfectants, flotation oils and plastics.

There will be marketed from this plant after the coal is distilled and all of the valuable by-products taken from it approximately 175,000 tons of a domestic smokeless fuel possessing all of the advantages of anthracite with none of its disadvantages such as high ash, of a value of over $1,750,000 a year.

Standardization of Electric Motor Frames

Standardization of certain important dimensions governing the interchangeability of electric motors of different makes has made a forward step, according to an announcement by the American Engineering Standards Committe, with the recent acceptance by two prominent organizations, the American Society of Mechanical Engineers and the National Electrical Manufacturers Association, of joint leadership in the development of such standards.

Machinery everywhere is more and more becoming motorized, being either driven by self-contained electric motors or adapted to easy application of motor drive upon installation.

Safety First in the Foundry

By A. A. Mowbray

Perhaps nowhere in industry is the necessity for a well balanced safety program better exemplified than in the foundry. There are certain shops or factories, no doubt, where emphasis must be laid upon the safeguarding of machinery; others where the greater part of safety effort may be directed toward education of the worker in safe practices. But in the foundry only the most thorough preparation along both these lines will avail to protect the worker adequately against the many hazards he must encounter.

To step into one of these modernly equipped foundries today, which proudly boast records of five or eight, or perhaps ten, years without a fatal accident and long periods without a lost-time injury, is to perceive at once a veritable "safety atmosphere" that is exemplified by everything the eye falls upon. And inquiry does not fail to discover that back of the daily foundry activity there is an intensive safety organization, including both executives, foremen and workmen, which has set a very high standard in cooperative safety effort.

It is self evident that preaching "safety first" principles and exhorting men to "watch their step" will be of little avail if management does not at the same time strive to eliminate the hazards which intelligent safeguarding will remove. Men are not deliberately careless, they are thoughtlessly careless; the goal in safety education is to make them thoughtfully careful. But before they will enter wholeheartedly into any organized safety plan, they must see the mechanical hazards around them and the physical dangers of the workplace removed.

It is impossible to discuss in a short space many of the phases of foundry safety. These may be found thoroughly outlined in the National Safety Council's Safe Practice Pamphlets Nos. 73, Me. 1, 35, 16, 22 and others. But from the point of view of protection of the individual a few may be emphasized.

Efficiency as well as safety demands that the foundry place be thoroughly organized. Elements of this plan will be adequate floor area, generous spacing, smooth walkways and open spaces, good lighting and sufficient ventilation. The smoke and murk of the foundry cannot be wholly eliminated, but scientific overhead ventilation, with fans if necessary, will do much to remove possibility of obscured hazards and will speed up the work. Lighting from large windows, although the best, is frequently inadequate for clear vision and must be supplemented with clusters of incandescent bulbs. Smooth walk surfaces and generous spacing between furnaces, other machinery and piled materials cannot be emphasized too strongly, since a high percentage of accidents in all foundries is traced directly to stumbling and falling against objects.

Cupolas, furnaces, ovens and other machinery must be grouped, for brevity, and the general admonition suffice to have all these pieces of the latest possible design and equipped with all necessary safety devices. Shields should be employed wherever practicable to protect the employee from excessive heat and furnace glare. Crucibles should be inspected with great care at frequent intervals. All tools and handling appliances should be kept in the highest state of repair and such accessories supplied as will help the workman to avoid unnecessary danger.

It is not always possible, of course, to supply labor saving devices that have become accessible, but where facilities will permit an overhead track and a traveling hoist with tongs supporting the crucible will be found of great safety advantage in transporting molten metal. A recent article in the June issue of the National Safety News showed an interesting picture of the molding floor where this method is employed, and illustrated how space, economy and efficiency all combine to recommend the method. Where molten metal is trundled over the floor by means of small hand buggies, the necessity for firm and smooth floor surfaces is again apparent.

Of great importance also is the selection of proper clothing for the foundry worker and such supervision as will insure his wearing all articles necessary for safety. Goggles, gloves, leggings and shoes of stout and serviceable pattern are essential. Regardless of occasional complaint about the fogging of goggles, this in most cases can be overcome and the worker will continue to use them if he understands that it is obligatory. Moisture on the goggles usually comes from sweat on forehead and eyebrow, and may be controlled by a light cloth band.

Regardless of the common belief that a foundry is a place so dirty that the principles of good housekeeping should not apply, there is no department where careful housekeeping is more essential. Housekeeping means order, good sense in arranging materials for convenience, avoidance of top-heavy piles, clear aisles and walkways, tools in their proper place, removal of accumulations of dirt and refuse. All these are essential to efficiency and are necessary for adequate safety in the foundry. In the recent accident reports of a large Michigan plant two fatalities arose from the regrettable habit of allowing materials to be piled insecurely alongside narrow walkways.

Education in safe practices may, perhaps, accomplish its greatest success in the foundry by teaching every employee the importance of good housekeeping. He must naturally be alert and intelligent if he is to meet successfully day by day the many imminent hazzards that are necessary about his work. Instruction in the many small safe practices advisable in handling and storing materials will be readily absorbed, and, led by the example of his foreman and safety committeemen, he will undertake with thoughtful care the removal of any hazard that might detract from the factor of safety.

STATEMENT OF THE OWNERSHIP, MANAGEMENT, ETC., OF

The Blast Furnace and Steel Plant

(Required by the Act of Congress of August 24, 1912)

Name of Publication: **The Blast Furnace and Steel Plant,** published monthly at Pittsburgh, Pa. (Report of October, 1927.)

Publisher—Steel Publications Inc., 108 Smithfield St., Pittsburgh, Pa.

Editor—Donald N. Watkins, 108 Smithfield St., Pittsburgh, Pa.

Managing Editor—Charles Longenecker, 108 Smithfield St., Pittsburgh, Pa.

Business Manager—Donald N. Walkins, 108 Smithfield St., Pittsburgh, Pa.

Names and addresses of Stockholders holding 1 per cent or more of total amount of stock:

Donald N. Watkins, 108 Smithfield St., Pittsburgh, Pa.

L. L. Carson, 722 Ulysses St., Pittsburgh, Pa.

C. J. Keller, 935 Heberton Ave., Pittsburgh, Pa.

M. M. Zeder, 108 Smithfield St., Pittsburgh, Pa.

Known bondholders, mortgagees, and other security holders holding 1 per cent or more of total amount of bonds, mortgages, or other securities: None.

DONALD N. WATKINS, Business Manager.

Sworn to and subscribed before me this 3rd day of October, 1927.

CHAS. A. SEIBERT, Notary Public.

(My commission expires March 6, 1931.)

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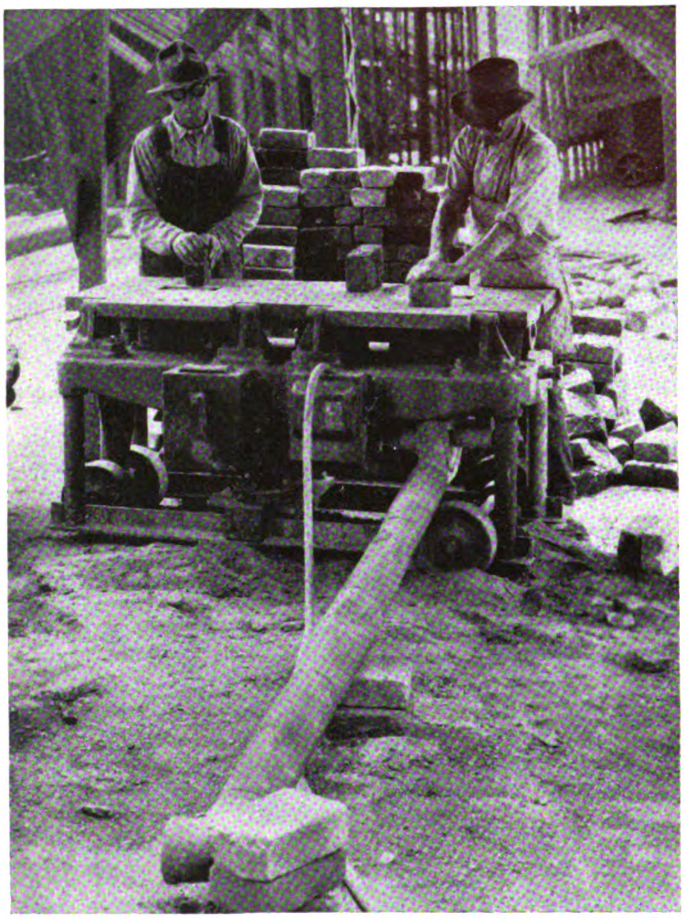
WITH THE EQUIPMENT MANUFACTURERS

Brick Cleaning Machine

The Rotor Air Tool Company has developed a new machine for the reclaiming of open-hearth checker brick, blast-furnace brick, soaking-pit brick, ordinary building brick, and paving brick. It is claimed that the machine removes the scale from refractory and regenerative brick, also the clay from blast furnace brick, and mortar and cement from ordinary paving and house brick. The machine may also be used for cleaning skew backs and the general shaping of brick.



Brick cleaning machine—Showing exhaust connection operated to clean burnt cinder from open hearth checker brick, in prominent steel mill.

The machine consists of a main table below which is mounted a main shaft running in Hyatt roller bearings. Two special cutting heads containing the cutting members are mounted on this shaft with special provision for the quick and convenient installation and removal of cutters. The two cutting heads project slightly through two slots or ports in the table. The table itself is hinged at the back end with a positive screw adjustment to raise or lower the forward end of the table. This adjustment gives the desired amount of contact and blow required for the brick being cleaned. The bricks are handled in exactly the same manner that a piece of wood is planed or shaped on a wood joiner.

The openings in the table are directly connected to an exhaust blower which drives the dust and lighter material removed to a convenient place. Immediately below the cutter heads themselves two automatic dump doors are mounted. These are counterbalanced so as to trip and discharge waste material automatically as an accumulation is formed.

A dust proof motor of ample power is provided, mounted on a hinged and counterbalanced motor base which automatically provides belt tension and takes up belt stretch. The entire machine is mounted on a four-wheel truck arrangement with a heavy steel tongue which makes it readily portable and permits it to be rolled from place to place or to be pulled by a tractor.

It is claimed that with a crew of three men this machine will clean 3,000 9-in. brick per 10-hr. day. This compares with the maximum production of 900 9-in. brick for the three men under the usual hand shipping methods. Tests have shown that the actual cost is usually less than 1 cent per brick, including interest on investment, cost of cutters, current consumption and direct labor cost.

Each head on the machine deliveres 600,000 blows per minute. The surface of the finished brick is entirely free from scale, and it is claimed the breakage is practically negligible because of the lightness of the individual blows. The machine may be adjusted to perform satisfactorily on a great variety of sizes and types of brick.

Link-Belt Sykes Herringbone Speed Reducer

This speed reducer can be economically applied to all classes of service no matter how light or heavy it may be. Distinct advantages are quietness of operation, high efficiency and ability to withstand shocks.

Three standard units have been developed to cover a wide range of ratios and capacities. The single reduction unit designated as type "S" covers ratios up to 10 to 1. Types "D" and "DV" are double reduction units. Type "D" is designed for heavy duty and ratios are from 10 to 1 up to 80 to 1. Type "DV" is a light duty reducer. Ratios range from 10 to 1 up to 130 to 1.

Link-Belt Sykes Herringbone Gears are the backbone of this speed reducer. The teeth run continuously across the face of the gear giving a good bearing surface with the several teeth engaged. The pinions are of heat treated alloy steel cut integral with the shaft.

The unit has a minimum number of parts. Oversize Timken bearings are used. Gears rotate within a large oil reservoir and bearings are splash lubricated. This provides ample lubrication. Special oil baffles at shaft projections keep dust out and oil in. The housing is free from troublesome oil grooves and oil wipers.

This product is manufactured at 2045 Hunting Park Avenue, Philadelphia, and on the West Coast by the Link-Belt Meese & Gottfried Company, Nineteenth and Harrison Streets, San Francisco.

Portable Grinder

The Buckeye Portable Tool Company, general offices and works Dayton, Ohio, has brought out a unique air tool for the polishing and grinding of all flat surfaces.

The tool is 27 in. long over all, 4½ in. in diameter at largest point, weighs but 15 lbs. complete, has 6,000 rpm. and has a polishing capacity or surface of 6 in. to 9 in. in width.

Like all the Hercules tools made by this company, its principle is unlike any other air tool on the market. All pistons, connecting rods, etc., being eliminated—an entirely modern adaption of the old and well proven rotary principle being employed.

It has but four moving parts, all of which can easily be held in one hand.

This simplicity of construction permits extreme lightness—an important factor in a tool for the work intended.

The fact that it is a rotary instead of a reciprocating movement eliminates all jar and vibration—giving an extremely smooth running tool.

The operator takes the tool in both hands, places the polishing wheel over the part wanted to be polished, presses on the safety control valve in the handle nearest where the air enters and the tool is in instant operation.

Electric Hoist

The American Engineering Company announces the "Quick-Life," a moderate priced, all-steel, quarter-ton electric hoist.

This is a high speed hoist with pressed steel frame, chrome-manganese steel in gears and shafts, ball bearings, non-spinning hoisting rope, oil bath lubrication, push button control and upper and lower limit switches. All working parts are fully enclosed.

The hoist weighs 200 lbs. and is made in two types—plain trolley and hook suspension. The plain trolley type requires 16-in. headroom and the hook suspension type 18-in.

This hoist was shown in operation for the first time at the National Machine Tool Builders Exhibition at Cleveland, in connection with the exhibit of the Gisholt Machine Company.

Melting Pot of Small Capacity

A new electric melting pot has been introduced for melting solder, lead, babbitt, tin, etc., which has a capacity of from 27 to 40 lbs., according to the metal to be melted. This pot may be operated on either 110 or 220-v. a.c. or d.c. circuits and is made in two ratings, 750 and 1,000 w.

The new pot is a General Electric product and is the smallest size of the G.-E., RP form E line. It consists of a durable sheet steel cylindrical casting 10 in. deep and 9 in. in diameter, in which is supported a cast iron crucible 4 in. deep and 6 in. in diameter, inside. The space between the crucible is efficiently insulated with a compact heat insulator.

Heating units are of the cast-in, sheath-wire type so successfully applied to metal melting. One unit is used in each pot, dissipating 750 w. in one rating, and 1,000 w. in the other.

The leads of the unit are brought over the top of the pot into a connection box fixed to the unit itself.

The new pot is designed for melting lead, babbitt, tin, solder and similar alloys or metals, except spelter or zinc, at temperatures not exceeding 950 deg. F. Detailed capacities follow: for 50/50 solder, 30 lbs.; for lead, 40 lbs.; for babbitt, 37 lbs., and for tin, 27 lbs. The approximate shipping weight is 50 lbs.

COMING MEETINGS

Oct. 7—The Eastern States Blast Furnace & Coke Oven Association. Fall meeting at the Shannapin Country Club, Pittsburgh, Pa. W. H. Honen, secretary.

* * *

Oct. 10-13—First National Fuels Meeting, Fuels Division A.S.M.E., St. Louis, Mo. Edwin C. Moody, chairman, 1932 N. Broadway, St. Louis.

* * *

October 10-13—American Society of Mechanical Engineers, First National Fuels Meeting. St. Louis. Victor J. Azbe, chairman, 6625 Delmar Boulevard, St. Louis, Mo.

* * *

Oct. 10-14.—American Gas Association annual meeting. Stevens Hotel, Chicago, Ill. Alexander Forward, managing director, 420 Lexington Avenue, New York City.

* * *

Oct. 17-20—National Hardware Association of the United States convention. Marlborough Blenheim Hotel, Atlantic City, N. J. Geo. H. Fernley, secretary, 505 Arch Street, Philadelphia, Pa.

* * *

Oct. 18-20—The Annual Aeronautic Meeting. The Waldorf Astoria Hotel, New York City. E. P. Warner, chairman.

* * *

Oct. 20-22—American Gear Manufacturers Association semi-annual convention at Mount Royal Hotel, Montreal, Quebec, Canada. T. W. Owen, secretary, 2443 Prospect Avenue, Cleveland, Ohio.

* * *

Oct. 25-27—Annual Transportation meeting, Hotel Sherman, Chicago, Ill. F. J. Scarr, chairman.

* * *

Oct. 25-29—American Institute of Steel Construction, fifth annual convention, Pinehurst, N. C. Charles F. Abbott, executive director, 285 Madison Avenue, New York, N. Y.

New Girder and Beam Sections

The Bethlehem Steel Company has enlarged its line of sections by the addition of an 18 girder and 31 I-beam sections. The girders range from a 30-in. section weighing 173 lbs. to the foot to a 15-in. girder with sections weighing 127.94 and 64.5 lbs. The I-beams range from a 30-in. section weighing 110 lbs. to a 10-in. one with 28.5 and 21-lb. sections.

TRADE NOTES

The Lo-Hed Hoist Division of the American Engineering Company announces the appointment of direct factory representatives in Pittsburgh and Cleveland for the sale of its Lo-Hed mono-rail electric hoists. The Pittsburgh office, whose territory will include Western Pennsylvania, West Virginia and counties along the Eastern border of Ohio, is located in the Oliver Building with D. A. Polhemus in charge and John Kaiser assisting. W. C. Minier will direct sales in Northern Ohio, except for territory surrounding Toledo, with offices at 2195 Bellfield Avenue, Cleveland.

* * *

Freyn Engineering Company has reopened its office in England at 38 Victoria Street, Westminster, London. Cable address "Vilvalle" London. At its home office in Chicago the company is organizing a department to handle its foreign business, notably the recent contracts with Soviet Russia, Germany and Luxembourg. The existing organization will continue to devote its efforts to the company's American business.

* * *

The Wellman-Seaver-Morgan Company, Cleveland, Ohio, announce the incorporation of an associated company in Canada known as the "Canadian Wellman-Seaver-Morgan Company, Limited." The head office will be at 307 Reford Building, Toronto, Canada, and a branch office at 808 Drummond Building, Montreal, for the handling of this company's products, which include coal and ore handling machinery; mining machinery, special cranes, port and terminal equipment, steel works equipment, coke oven machinery, gas producers and other specialties.

* * *

Announcement is made of the purchase of the controlling interest in The American Resistor Corporation of Milwaukee, Philadelphia and New York by The Carborundum Company of Niagara Falls, N. Y. The principal products of The American Resistor Company are non-metallic electrical heating elements and resistors which are marketed under the trade name of "Globar." The new company will be known as Globar Corporation and has been incorporated under the laws of the State of New York. The present manufacturing facilities of the old company will be moved to Niagara Falls, N. Y., where a new plant will be erected in connection with the plant of The Carborundum Company. "Globar" is a carborundum product being produced in the form of rods or bars of carborundum. The Globar element has a wide application both in the industrial and in the domestic fields. For instance it has met with great success in providing a quick, closely controlled, clean heat in heat treating and tempering furnaces, forging furnaces, annealing furnaces, etc., and has met with outstanding success in automobile and other industrial plants.

In reorganization, Jos. A. Steinmetz, president; W. E. Deurstin, vice presdent; and Walter W. Perkins, vice president and treasurer have been succeeded by Frank J. Tone, president; George R. Ravnor, vice president; F. H. Manley, treasurer and Arthur Batts, secretary. These are also directors of the Globar Corporation, together with Messrs. Steinmetz, Perkins and Sharpe of the old group.

* * *

A voluntary petition in bankruptcy was filed late in September in Federal Court by the Rogers-Brown Iron Company, manufacturer of pig iron. The move was authorized by the board of directors.

* * *

Announcement was made Friday, September 16, by the British Empire Steel Corporation that its estimated 1928 output at the Bell Island iron mines, Newfoundland, of 1,300,000 tons was contracted for. Of this amount 800,000 tons will go to Germany, 400,000 tons to the company's furnaces in Nova Scotia and 100,000 tons to the United States.

* * *

A battery of coke ovens estimated to cost several million dollars is being planned for erection at Columbus, Ohio, by the Koppers Company. Approval of a change in the franchise of the Ohio Fuel & Supply Company, whereby coke oven gas can be mixed with the present supply of natural gas, is essential before plans can be definitely completed. However, this approval, by the City Council of Columbus is expected shortly. The coke will in all probability go to the American Rolling Mills Company, and the extra supply of gas will be taken care of by local industrial plants.

Course of Industry Is Westward

In January, 1908, the center of industry in the United States was on the northern boundary of Indiana, about 110 miles east of Chicago. In January, 1918, it was still on the northern boundary of Indiana, but had moved about 50 miles nearer to Chicago. In January, 1926, it had moved 25 miles to the southwest of its position in 1918 and was about 50 miles southeast of Chicago. The total movement in the 18 years from 1908 to 1926 was about 75 miles in a west by south direction. This slow movement of the center of industry during a period when the capacity of prime movers in central stations and manufacturing plants increased about 140 per cent indicates that industrial development in the United States is proceeding at about the same rate in all sections, but a trifle more rapidly in the western and southern parts of the country.

These determinations of the center of industry, which have been made by the Geological Survey, Department of the Interior, are based on the capacity of steam engines, steam turbines, water wheels, and internal-combustion engines installed in manufacturing plants and in public-utility power plants. Twice the weight is given to the power equipment in public-utility power plants, as it is used twice as much as power equipment in manufacturing plants. Previous determinations of the center of industry have been based on the installed capacity of prime movers in manufacturing plants only. It is believed that more representative results are obtained by using the capacity of power equipment in both manufacturing and public-utility plants.

The geographical center of the United States is near the center of the northern boundary of Kansas, and the center of population is in Owen County, southwestern Indiana.

NEWS OF THE PLANTS

The Ford Motor Company has adopted a Semet-Solvay acid washer for the light oil and benzol recovery plant of the by-product coke ovens at Dearborn. This washer will eliminate impurities from the crude benzol liquor by means of a sulphuric acid bath. The process separates such substances as phenol and sulphur while preserving for further refinement the elements desirable for making high-quality automobile fuel.

* * *

The Allegheny Steel Company, Brackenridge, Pa., has acquired the Delaware Seamless Tube Company, Auburn, Pa., near Reading. This latter produces hot rolled and cold drawn tubes up to 3½ in. outside diameter. The owners are making changes in the plant and will use it primarily for the manufacture of alloy steel tubing, although they will still sell the products of the old company. The Allegheny Steel Company has for years been making welded tubes besides marketing seamless tubing made by another company.

* * *

The Witt Steel Company of Greensburg, Pa. announces a change in the company name from The Witt Steel Company to The Witt Humphrey Steel Company. This change, which will go into effect immediately, is in name only and will in no way effect its present policies.

* * *

The new skelp mill of the Reading Iron Company is rapidly nearing completion. Hopes are entertained that it can be placed on production by December 1.

* * *

Bethlehem Steel Company announces the appropriation of $25,000,000 to $30,000,000 for the erection of warehouses at Los Angeles, San Francisco, Portland, Ore.; Seattle, and possibly at Victoria or Vancouver, B. C. This appropriation also includes the cost of building several new freighters for intercoastal activities.

* * *

The new mechanical puddling plant of the H. M. Byers Company has recently been put into operation. It is said that wrought iron made by this process is more durable and comparable in cost to steel.

* * *

By blowing out its No. 1 blast furnace at the Ohio Works, The Carnegie Steel Company, now has but three of its six stacks in blast in that district.

* * *

Although the Whalen interests have bought a large block of Pressed Steel Car Company common stock, there has been no discussion concerning a merger with General American Tank Company according to F. N. Hoffstot, president of the former company, on his departure for Europe. While such a merger is not improbable, Mr. Hoffstot thought it a remote possibility.

* * *

The Surface Combustion Company, 366 Gerard Avenue, New York City, makers of furnaces and fuel burning equipment, has purchased the plant of the Tower Textile mills, Toledo, O., and will remodel and equip it for manufacturing purposes. The works will be equipped for the manufacture of ovens, gas burners and kindred products.

Conference on Engineering Materials in Berlin, 1927

The preparations for the Conference on Engineering Materials, which is to take place in Berlin from October 22 till November 13 have already far advanced. The sponsors of this convention are the great German scientific engineering associations, which are supported by various German industrial organizations and the exhibitions, fairs and foreign visitors office of the city of Berlin. The program of papers contains about 200 lectures to be read by scientists and practical engineers. Foreign scientists will be the speakers especially in some series of lectures to be held on October 31. While these papers, which are read at the Technical University of Charlottenburg are intended chiefly for engineers, an exhibition of engineering materials arranged in the Neue Ausstellungshalle on the Kaiserdamm will be an attraction for the general public also. This exhibition will not bear the character of a common trades fair, but will be arranged according to scientific principles. There will be seen the most up-to-date methods of material testing and demonstrations of the properties of the different engineering materials, the way of employing and of working them.

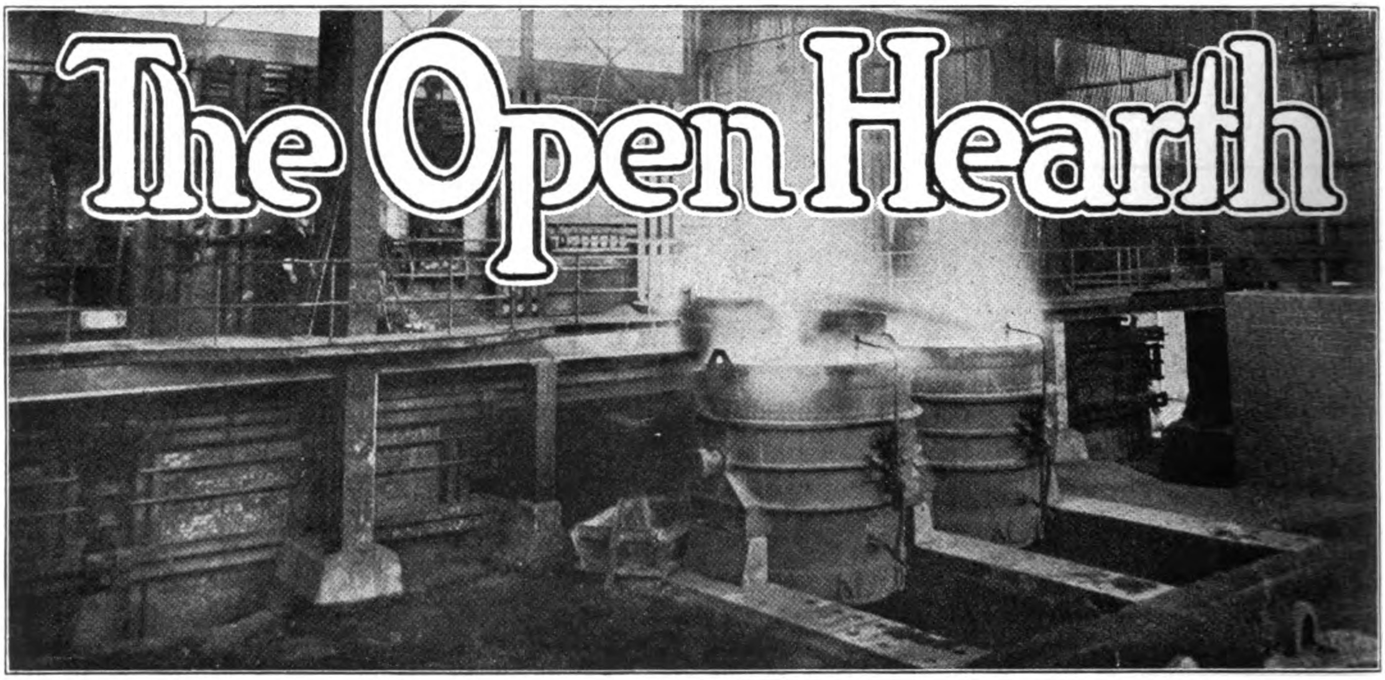
Three groups of engineering materials will be dealt with, namely: Iron and Steel, Non-ferrous Metals and Electrical Insulation Materials.

More than 200 testing machines, which will be shown in operation will introduce the visitors into the latest methods of testing, which are not familiar even to many engineers. Beside the practical demonstrations there will be drawings, photographs, lantern slides and films, to further the understanding of the problems to be dealt with by this Conference on Engineering Materials. The road to progress today leads to co-operation in engineering more than is the case in other fields of human activity. It is the special task of this convention to bring together the large class of producers and the still larger community of consumers for the purpose of co-operative work.

An epitome of all that is shown at the conference on engineering materials, will be given in a practically arranged hand-book, which will be published on this occasion. This bulky work will be of equal use for the producing and for the consuming industries. To facilitate interleaving appendixes or the like the hand-book will be provided with a special loose binding. Many inquiries on the part of foreign diplomats accredited in Berlin prove that the continental and oversea engineering world is highly interested in this new and unique congress.

Detailed particulars are given by the "Geschäftsstelle der Werkstofftagung," Berlin NW7, Ingenieurhaus.

The Open Hearth



Mr. John K. Furst, formerly vice president and chief engineer of the Pennsylvania Engineering Works, New Castle, Pa., on September 1, 1927, became general manager of The S. R. Smythe Company, Pittsburgh, Pa. Mr. Furst, who for some years past has been engaged in the engineering and building of blast furnaces and steel plant equipment, brings to this company a ripe experience along general engineering lines. The company in addition to doing a general engineering business expects to specialize in open hearth and heating furnaces, soaking pits, hot metal mixers, Bessemer converters, duplex steel plants, blast furnaces and steel plant equipment.

* * *

N. R. Crawford, for several years director of sales for the Industrial Works, Bay City, Mich., has resigned, effective October 1. No announcement has been made as to his future connection.

* * *

George F. Mosher, assistant to the treasurer of the General Electric Company, has been named auditor of disbursements succeeding C. H. Stull, who has become treasurer of the Ohio Contract Purchase Corporation, an associated company with headquarters in Cleveland.

* * *

T. F. Barton, of the central station engineering department of the General Electric Company at Schenectady, has been appointed engineer of the New York district, with headquarters at 120 Broadway, New York, Vice President E. W. Allen has announced.

J. B. Bassett of the New York office, has been named executive engineer of the New York district.

J. E. Montgomery has been appointed vice president in charge of operation, Wheeling Steel Corporation. In this capacity he succeeds G. W. Moore, who has resigned.

* * *

M. J. Myers, formerly associated with Columbia Steel Company, has been appointed assistant to the vice president, J. S. Hammond of the Superior Steel Steel Company, and Norman F. Mellville becomes manager of inspection and metallurgy.

Both appointments went into effect September 1.

* * *

R. L. Wilson, formerly works manager of the Westinghouse Electric & Mfg. Company, has been appointed assistant to F. A. Merrick, vice president and general manager. His successor as works manager will be J. M. Hepple, for some years manager of the motor engineering department.

Paul Hecht, previously associated with the South Philadelphia Works, has also been promoted to assistant to the vice president.

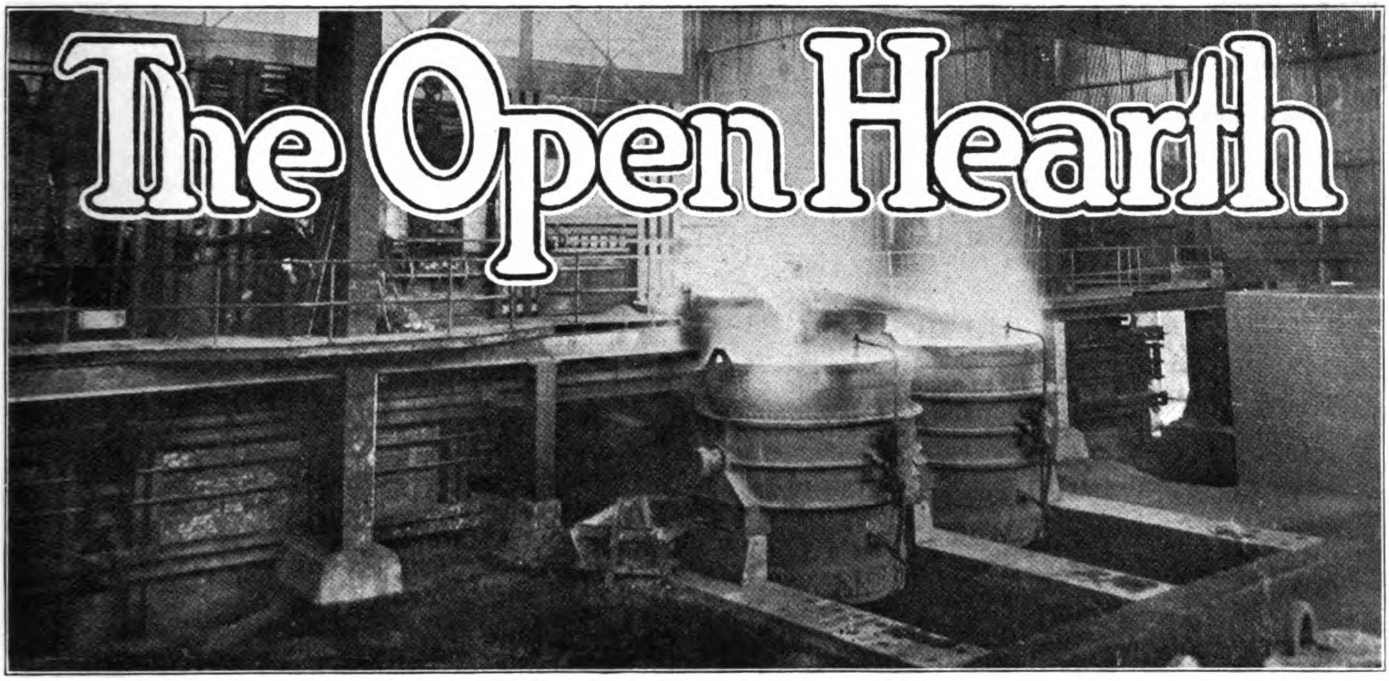
* * *

D. W. Blakeslee is the new illuminating engineer of the Pittsburgh Reflector Company. Mr. Blakeslee has been engaged in civil, mechanical and electrical engineering for the past 17 years. Since 1919 he has been electrical engineer for Jones & Laughlin Steel Company, which firm he left to take over his present position.

* * *

G. W. Vreeland has recently been appointed assistant general manager of operations of the Weirton Steel Company. In this capacity he will act as assistant to J. C. Williams, vice president and general manager.

Mr. Vreeland, after graduating from Cornell, in the class of 1898, became associated with the Cambria Steel Company, Johnstown, Pa., where he remained for three years. From there he went with Carnegie Steel Company as master mechanic, blast furnace department, Duquesne, Pa. works. Since then he has served with Carnegie Steel Company as assistant



The Open Hearth

superintendent of blast furnaces, Duquesne works; superintendent of Mingo, Bellaire and Steubenville furnaces, and assistant general superintendent Mingo and Bellaire, Ohio works. From the latter position he resigned to take his present one with Weirton.

* * *

A. K. Lewis, formerly director of personal service of The American Rolling Mill Company of Middletown, has been made vice president of The Columbia Steel Company in charge of operations at both Butler and Elyria. David Thomson is works manager at the Butler plant.

* * *

John Follansbee has succeeded his brother, William U. Follansbee, as president of Follansbee Brothers Company, Pittsburgh. The retiring president has been made chairman. The newly elected president has been associated with the company since its inception. He has served in the shipping, invoicing and sales departments. For some time he has been general manager of sales and a few years ago became vice president. He will continue to serve in his present capacity as president of Sheet Metal Specialty Company and Lustro Coated Sheet Company, subsidiaries of the parent concern. Charles A. Wilson will succeed Mr. Follansbee as general manager of sales.

* * *

Robert S. Quinn is now assistant general superintendent of the Mingo Junction Works of the Carnegie Steel Company, where he was formerly master mechanic. He received his present appointment on the resignation of Mr. Geo. W. Vreeland. Mr. Quinn's former position will be filled by Hugh B. Conover.

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Jas. A. Henry, for some time Detroit district sales manager for the Columbia Steel Company, has left this firm to become assistant manager of sales for the Weirton Steel Company.

* * *

C. G. Emil Larsson has been appointed chief consulting engineer for the American Bridge Company, New York City. Mr. Larsson was born and educated in Sweden, where he graduated from the Technical High school of Stockholm in both mechanical and civil engineering. He came to this country in 1888 and procured a position as draftsman with the Wrought Iron Bridge Company, Canton, Ohio. Later he became associated with the Edgemere Bridge Works, where he served as a draftsman and designer until their absorption by the American Bridge Company. With this concern he worked as a designer, division engineer, and since 1904 as assistant chief engineer. Concurrent with the above announcement was that of the appointment of J. H. Edwards as chief engineer of the same concern. Mr. Edwards has been actively associated with the structural steel business since 1888 and has been with the American Bridge Company since 1900. He is vice president of the American Welding Society.

* * *

R. C. Good, formerly chief metallurgist of the Columbia Steel Company, has left that concern to become affiliated with the Electro-Metallurgical Sales Corporation, New York City. He will work with the Pittsburgh office, Oliver Building, Pittsburgh, as an associate to R. S. Poister.

* * *

W. R. Bean, for 11 years research engineer of the Eastern Malleable Iron Company, Naugatuck, Conn., has been chosen vice president and consulting engineer of the Grindle Fuel & Equipment Company, Harvey, Ill. He has served 26 years in the malleable foundry field, of which 12 years were with the Symington Company of Rochester, N. Y.

George P. Grant Now Western Manager for Steel Publications Inc.

George P. Grant has resigned as vice president of the Iron and Steel Publishing Company and will be Western Manager of Steel Publications Incorporated.

Mr. Grant for a number of years was Sales Manager of The Blast Furnace and Steel Plant and Forging-Stamping-Heat Treating. He brings to the West a direct contact between the publishers of these magazines and their clients.

TRADE PUBLICATIONS

The "Utilization of Blast Furnace Slag in Highway Improvement" is the title of a Technical Series Bulletin issued by the Missouri School of Mines, Rolla, Mo. It is edited by Clarence E. Bardsley, Sc. D., Associate Professor of Civil Engineering.

This bulletin contains 115 pages and 17 illustrations; 8 tables, 39 pages of descriptive matter and a bibliography of 600 references.

Professor Bardsley follows the discussion on the nature and purpose of the investigation with Chapter I, which gives a resume of the history, manufacture, and use of slag as a structural material. He sketches the history of the uses of slag from the earliest Roman times through Germany, England and other countries in Europe and the Orient to its present uses in the United States. A concise description of the manufacture of slag is taken up from the processes at the blast furnace up to the time it becomes a construction material. Slag as a structural material is then described and its uses discussed. This discussion is concluded by tables summarizing the specifications for slag in highway construction as given in the specifications of many State Highway Departments, the U. S. Bureau of Roads, etc.

Copies of this paper may be obtained on application to the Librarian of the Missouri School of Mines, or to the Author. Address requests on letterheads.

* * *

"Electricity—The Pathway of Prosperity:" This attractive publication just published by the Westinghouse Electric & Mfg. Company treats very broadly the economic problems of rural electrification. In the booklet there are included a number of tables giving a great deal of valuable data pertaining to the proper installation and use of electrical equipment on the farm. Among other things these tables show the size of motor which should be used on various pieces of farm equipment, and the cost of driving this equipment.

* * *

Power plant engineers will be interested in catalog No. FF-2, now being distributed by the Combustion Engineering Corporation. This catalog describes the C-E Fin Furnace which is formed of water-cooled tubes backed by a refractory material. Illustrations show the manner of constructing the furnaces for various types of boilers. Copies of the catalog may be obtained upon request by addressing the corporation at 200 Madison Avenue, New York City. The same corporation has mailed reprints entitled "100,000 Horsepower Steam Auxiliary Station" and "Paper Mill Installs New Boiler Plant." The former describes the power generating equipment installed at the Buck Steam Station of the Southern Power Company, while the latter is a similar description of equipment placed in the Three Rivers plant of the Canadian International Paper Company.

Leaflets received from the General Electric Company contain descriptive matter covering the following products:

Air Compressor Governors, Squirrel Cage Motors —"500 Series," Adjustable Varying Speed Motors—Type BSR, General Purpose Synchronous Motors—"7500 Series," Type BTA Motors, Vertical Induction Motors—"500 Series," Totally Enclosed Induction Motor—New Form R, Jack Type Disconnecting Switches, Air Heating Units.

* * *

In a well illustrated leaflet bearing the title "For Constant Operation Specify Hyatt Bearing" is enumerated the many applications of these bearings to blast furnace and steel mill equipment.

* * *

The Allen-Bradley Company, Milwaukee, Wis., is distributing revised bulletins and price sheets for electrical appliances which it manufactures.

* * *

"Geared Turbine Generator Units 75 to 500 kw. for A.C. and D.C. Operation" is the subject of a new and attractive leaflet, No. 20,293, recently issued by the South Philadelphia Works of the Westinghouse Electric & Mfg. Company. A number of photographs, showing the construction of these units, are included.

* * *

"Edmoore" Power Demand Limitator, a patented product is the heading on Bulletin No. 11, published by Edward T. Moore, manufacturer, 500 Cahill Building, Syracuse, N. Y. The "Limitator" is an electrical device for automatically controlling and limiting the power demands or peak loads on electric power systems for consumers. It is claimed that by its use many small plants are saving large sums every month. The device is generally connected to the main incoming power lines of a consumer's plant so as to summate all power.

The Limitator will control all types of load, such as motors, enameling, japaning and baking ovens, and annealing, heat treating, brass, steel and gray iron furnaces, in various industries such as silk mills, paper mills, glass works, rubber plants, coal mines, bakeries, foundries, machine shops, gear works, cement plants, salt mines, brass and steel mills, electric-chemical and others.

* * *

Some actual operating results using Indiana and eastern coals in Chapman Completely Mechanical Gas Producers are described in a folder just issued by The Chapman Engineering Company of Mt. Vernon, Ohio.

The figures and data presented in the folder are especially interesting, chiefly because they are taken from actual results obtained from the average operating conditions and not from special or trial runs.

The rather unusual results shown are explained by the improved fire-bed conditions, caused by the revolving ash beam at the bottom of the producer, which keeps the fire bed uniform even when the producer is operated at extremely high capacities.

This is a new and interesting development in gas producer design and is worthy of everyone's attention. Copies may be had by writing the home office of The Chapman Engineering Company at Mt. Vernon, Ohio.

* * *

Mackintosh-Hemphill Company, Pittsburgh, Pa., is distributing a four-page bulletin covering Adamite dies for pressed metal work. The physical characteristics of Adamite are described in the bulletin and several dies and the work they perform are illustrated. A list is given of the various industries in which Adamite castings have been successfully used to resist abrasion.

THE STEEL PLANT BRICK MASON

A Section Devoted to Items of General Interest to Blast Furnace and Steel Plant Brick Masons

Fire Brick Plant Merged

The Walsh Fire Clay Products Company of St. Louis, with works at Vandalia, Mo., will hereafter operate as a subsidiary of the Harbison-Walker Refractories Company as the latter company, has through an exchange of stock, obtained a controlling interest in the Walsh Company. By this acquisition the Harbison-Walker Company increased its daily output of fire brick by about 150,000 and secures one of the oldest plants in the St. Louis district.

J. H. Zellers, brickmason foreman of the American Steel Foundries, Granite City, not only directs the masons in his plant, but can, when occasion requires, "set the pace" in putting in a "back wall" or a "door jamb." He has six open-hearth furnaces to keep in repair.

Institute Meeting Postponed

The September 15 meeting of the American Refractories Institute, which was scheduled for Niagara Falls, Ontario, has been postponed, and will be combined later with a joint meeting of the American Institute of Chemical Engineers and the American Refractories Institute.

Silica-Carbide Refractories

At a recent meeting of the American Society for Steel Treating, the speaker, J. A. King, New England representative for the Carborundum Company, Niagara Falls, N. Y., talked on "Special Refractories for Heat-Treating Furnaces," Mr. King sketched the development of specialized silica-carbide refractories during the past nine years and pointed out the advantages and drawbacks of different applications. He also demonstrated the development in measures that can now be applied to overcome certain characteristics of these materials.

Ceramic Engineers to Travel

A tour for ceramic engineers has been planned by the American Ceramic Society, 2525 North High Street, Columbus, Ohio. The time consumed in making the trip will be from May 19 to July 5, 1928, inclusive. The route will be such as to include all important ceramic centers especially those in England, Netherlands, Germany, Czechoslovakia and France.

Bricks from Waste Sand

After more than half a century of persistent effort, it is reported in The Stone Trades Journal, a use has been found for the waste sands of St. Helens, England. These sands, of which large quantities are employed for glass polishing, have been accumulating to such an extent in past years that the town is dotted with numerous unsightly piles of this refuse from the glass plants.

Now, after fortunes have been lost in attempts to solve the problem, two men of St. Helens, Messrs. Peter Heaton and Horace Pardoe, claim that the sand is suitable for the making of bricks that are in every way equal to ordinary clay bricks. According to the inventors, who have worked on the problem for almost ten years:

"The bricks already produced have been tried by fire and water without revealing crack or flaw. They have been boiled in sulphuric acid for nearly a week, and then for several days in soda. Any brick than can stand tests like that is as good as anything on the market."

To Burn Brick in Continuous Kiln

Silica brick will hereafter be burned in continuous kilns in the plants of the Harbison-Walker Company as this company has contracted for the American rights for ovens of this type designed by Heinrich Koppers of Dusseldorf, Germany.

At present one kiln is being erected at the East Chicago works of the company, but eventually two more will be installed at this plant. Others will then be placed in operation in the works at Hays Run, near Pittsburgh, at Mt. Union, Pa., at Birmingham, Ala., and at Downingtown, Pa.

For some years the Harbison-Walker Company investigated the feasibility of burning silica brick in a continuous kiln and as a result of this investigation, President J. E. Lewis went to Germany to inspect developments in that country. At Dusseldorf, the Heinrich Koppers kiln was found to be in successful operation. This kiln is heated with producer gas, which, with the air, is heated in regenerators in order that a temperature of approximately 2,700 deg. F. may be obtained. Temperature control is assured by equipping the kiln with pyrometers and gauges for both draft and pressure determinations. In this manner the intensity of heat imparted to the brick as they pass through the several zones in the kiln can be accurately regulated. This feature is a most important one as success in burning brick is dependent on both the temperature control and the time element in heating. From the kiln the waste gases are conducted to a floor where the brick are dried before they are loaded on the cars which carry them through the kiln.

Before adopting the Heinrich Koppers kiln experiments were conducted on brick made from ganister rock, shipped to Dusseldorf from the Harbison-Walker quarries, and burned under the supervision of company engineers.

An initial expenditure of $1,500,000 has been made for the completion of the first unit.

Tentative Specifications for Clay Fire Brick for Malleable Furnaces with Removable Bungs and for Annealing Ovens*

1. These specifications are intended to cover only burned products made from fire clay by the usual processes of manufacture and containing not more than 55 per cent alumina or 85 per cent silica. Even within this range of composition, it is not intended to include products other than those regularly sold as clay fire brick.

Size Tolerance

2. Variations (plus or minus) of 2 per cent from specified dimensions covering both shrinkage and warpage shall be allowed on dimensions of 4 in. or over. On dimensions under 4 in., 3 per cent variation shall be allowed.

Test Requirements

Malleable Furnace Bungs:

3. (*a*) *Silica Content*—The silica content shall not exceed 65 per cent.

(*b*) *Softening Point*—The softening point shall not be below cone 31.

(*c*) *Spalling*—Brick as shipped, after subjection to an average of 18 dips in the spalling test, as described in Section 11, shall not show a loss of more than 20 per cent of their original weights.

(*d*) *Modulus of Rupture*—The modulus of rupture of the brick tested cold shall not be less than 200 lb. per sq. in.

Malleable Furnace Sidewalls and Bridgewalls:

4. (*a*) *Silica Content*—The silica content shall not exceed 65 per cent.

(*b*) *Softening Point*—The softening point shall not be below cone 31.

(*c*) *Spalling*—Brick as shipped, after subjection to an average of 9 dips in the spalling test, as described in Section 11, shall not show a loss of more than 20 per cent of their original weights.

(*d*) *Linear Change*—When duplicate samples are heated uniformly to a temperature of 1,400 deg. C., maintained at this temperature for 5 hours and cooled, they shall not show a contraction of more than 1.5 per cent of the original length.

Malleable Furnace Firebox Linings and Lower Stack Linings:

5. (*a*) *Softening Point*—The softening point shall not be below cone 31 in the case of the non-siliceous grade† and not below cone 28 in the case of the siliceous grade.†

(*b*) *Linear Change*—When duplicate samples are heated uniformly to a temperature of 1,400 deg. C., maintained at this temperature for 5 hours and cooled, they shall not show a contraction of more than 1.5 per cent of the original length.

Malleable Furnace Upper Stack Lining:

6. (*a*) *Softening Point*—The softening point shall not be below cone 28.

(*b*) *Linear Change*—When duplicate samples are heated uniformly to a temperature of 1,350 deg. C., maintained at this temperature for 5 hours and cooled, they shall not show an average contraction of more than 1.5 per cent of the original length.

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*American Society for Testing Materials.

†Brick are considered as being of non-siliceous grade when the silica content is 65 per cent or less and of siliceous grade when the silica content is greater than 65 per cent.

Elements to be Found in Brick*

Silica and lime are the major constituents of a silica brick, while in clays or clay refractories there are many more constituents to be determined, namely, silica, alumina, iron oxide, titania, lime, magnesia and alkalies. A brief description of these materials will be of interest.

Silica—Clean, white sand is nearly pure silica, as well as is quartz or ganister. It is present in most rocks and minerals, being the most common constituent of the earth's surface. Its melting point is high (3,200 deg. F.) and it is a principal constituent of clays.

Alumina—This material is second to silica in its abundance in the earth's surface, but it seldom occurs as a pure material, as does silica. It is usually in combination with other materials forming rocks and minerals, such as clay which is principally silica and alumina. Emery is fairly pure alumina. The melting point of alumina is very high (3,700 deg. F.).

Iron Oxide—Ordinary red iron ore is iron oxide, as is the rust which forms on iron. The oxygen of the air combines in a chemical way with the iron to form rust. Different oxides form (ferric and ferrous), depending upon the amount of oxygen that combines with the iron. Any of these oxides act as a flux with refractory materials, lowering their melting points.

Titania—This material is not very common in nature. Rutile is mainly titania. It is usually present in small amounts in clays, increasing in percentage as the alumina increases, so that diaspores contain as high as 5 per cent.

Lime and Magnesia—Both of these constituents are essentially the same in their properties. Lime is a common material which is made by heating limestone, while magnesia is made by heating or calcining magnesite. Both are very refractory when alone, but if mixed with clays they act as serious fluxes.

Alkalies—Soda and potash are the materials called alkalies. Ordinary lye is soda or sodium oxide. These materials are very active fluxes with any refractory. They melt at a red heat and form a vapor at higher temperatures.

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*Abstacted from Bulletin No. 14 of the American Refractories Institute.

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ANALYSES OF RAW CLAYS FROM VARIOUS PRODUCING DISTRICTS

	NEW JERSEY DISTRICT					MARYLAND DISTRICT		SOUTHERN OHIO DISTRICT
	Rockingham clay	Plastic clay (#32)	No. 1 fine clay	Plastic clay (#38)	No. 2 fine clay	Plastic clay	Flint clay	Plastic clay
Ignition loss	9.04	7.54	14.32	5.60	12.38	9.02	14.60	10.82
Silica	57.20	69.56	43.86	76.24	51.04	52.88	42.76	53.32
Alumina	25.78	20.34	38.81	15.76	32.31	33.61	39.15	29.47
Iron oxide	2.78	0.54	0.89	0.52	1.29	1.63	1.11	2.29
Titania	1.32	1.64	1.84	1.68	1.92	1.28	2.80	1.52
Lime	0.13	0.25	0.34	0.26	0.37	0.22	0.18	0.62
Magnesia	1.11	0.30	0.34	0.29	0.34	0.49	Trace	0.72
Alkalies	2.60	0.26	0.31	0.23	0.12	1.39	0.23	0.63
Total	99.96	100.43	100.71	100.58	99.77	100.52	100.83	99.39
P.C.E.*	27-28	30-31	Above 33	30	32-33	31-32	33-34	28-29

	PENNSYLVANIA DISTRICT					KENTUCKY DISTRICT			
	Monument flint clay	Cambria County bond clay	Clinton County flint clay	Dean flint clay	Westmoreland Co. plastic clay	Siliceous semi-flint clay	Soft semi-flint clay	Hard semi-flint clay	Black plastic clay
Ignition loss	14.50	12.68	13.82			8.86	14.40	14.08	9.66
Silica	43.48	44.60	42.76	50.61	56.65	65.04	46.16	43.46	55.92
Alumina	39.20	37.35	39.03	45.33	36.33	22.29	35.04	37.45	24.71
Iron oxide	0.74	1.17	0.77	0.77	1.79	1.13	1.42	1.19	4.79
Titania	2.20	2.16	2.72	2.44	2.95	1.60	2.44	2.80	1.52
Lime	0.31	0.30	0.30	0.26	0.35	0.21	0.27	0.30	0.34
Magnesia	0.26	0.42	0.37	0.10	0.66	0.47	0.49	0.64	1.01
Alkalies	0.08	1.57	0.14	0.24	1.23	1.38	0.64	0.93	1.57
Total	100.77	100.25	99.91	99.75	99.96	100.98	100.86	100.85	99.52
P.C.E.*	32-33	32-33	32-33	33-34	30-31	29-30	32-33	32-33	20-26

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*An abbreviation for pyrometric cone equivalent, which is a new term used in place of such expressions as fusion point, melting point and softening point.

	MISSOURI DISTRICT				COLORADO DISTRICT		
	Raw smooth flint clay	Raw Cheltenham clay	Raw plastic clay (B-291)	Raw burley flint clay	Flint clay	Plastic clay	Semi-flint clay
Ignition loss	13.86	11.96	12.10	13.30	12.24	6.16	14.16
Silica	43.32	54.78	49.62	34.62	54.06	70.82	49.02
Alumina	39.35	28.84	33.15	48.03	32.05	19.43	34.78
Iron oxide	0.77	1.98	1.55	1.09	0.49	1.03	0.72
Titania	2.00	1.64	1.56	2.28	1.00	0.84	0.96
Lime	0.16	0.43	0.13	0.25	0.43	0.18	0.39
Magnesia	0.33	0.72	0.93	0.56	0.25	0.44	0.24
Alkalies	0.22	0.21	0.97	0.44	0.12	1.37	0.37
Total	100.01	100.56	100.01	100.57	100.64	100.27	100.64
P.C.E.*	32-33	30-31	32	Above 33	32	27	32

ANALYSES OF MISCELLANEOUS REFRACTORY RAW MATERIALS

				Typical chromites			
Material	Ganister	Austrian magnesite	California magnesite	#1	#2	North Carolina cyanite	Diaspore clay
Ignition loss	.....	.....	.....	.....	.....	0.22	14.46
Silica	97.80	1.42	3.25	6.4	1.5	34.30	7.60
Alumina	0.90	0.41	2.20	8.0	15.0	65.10	73.70
Iron oxide	0.85	3.62		15.3	12.1	0.35	0.73
Titania	.....	.....	.....	.....	.....	0.05	2.95
Lime	0.10	.....	.....	1.2	0.7	0.41	0.24
Magnesia	0.15	.....	.....	16.1	14.0	0.10	0.23
Alkalies	0.40	.....	.....	.....	.....	Trace	1.03
Calcium carbonate	.....	2.65	2.32	.....	.....	.....	.....
Magnesium carbonate	.....	91.69	92.23	.....	.....	.....	.....
Chromic oxide	.....	.....	.....	53.1	56.8	.....	.....
	100.20	99.79	100.00	100.1	100.1	100.53	100.94
P.C.E.*	32-33	Above 35	Above 35	Above 35	Above 35	Above 35	Above 35

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*An abbreviation for pyrometric cone equivalent, which is a new term used in place of such expressions as fusion point, melting point and softening point.

Bulletin No. 14—American Refractories Institute.

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SAFETY FIRST IN THE STEEL PLANT

Section Devoted to the Interest of the Safety Movement

Judge Gary Remembered

By a silent, rising vote, delegates to the Sixteenth Annual Safety Congress on September 26 paid their final tribute to the memory of Judge Elbert H. Gary, Chairman of the Board of the United States Steel Corporation, who was an honorary member of the National Safety Council.

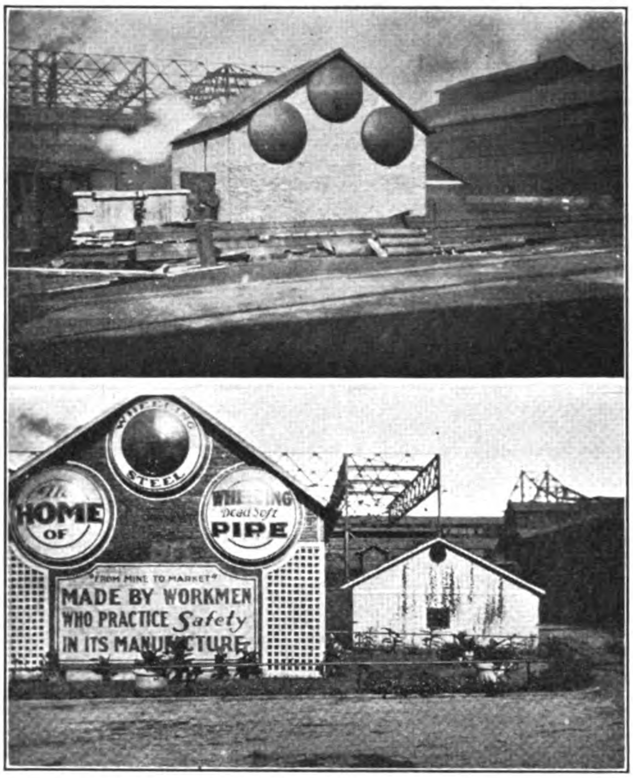
Salient Facts About the National Safety Council

The first safety congress was held at Milwaukee, 1912, and a formal organization meeting was held in New York City in 1913, when the body was originally started as the National Council for Industrial Safety, a name which was changed inasmuch as the scope of the institute broadened to include safety on the streets and highways, in other public places, at home, on the sea and in the air.

The first president was Robert W. Campbell, attorney for the Illinois Steel Company, a son-in-law of the late Judge E. H. Gary, who was one of the early safety leaders.

The first secretary was William H. Cameron, who is still with the organization, now serving as managing director.

The first congress held in Chicago was in 1914.



According to "Pete" Haberstick, Safety Director of the Wheeling District of the Wheeling Steel Corporation the cause of Safety First can be promoted and the landscape made more attractive by decorations such as shown above. One would hardly recognize the unsightly oil house above as it appears in the lower photograph

Safety Conference to be Held at Columbus

A safety conference and exhibit will be held at Columbus, Ohio, November 9 and 10, under the auspices of the Industrial Commission of Ohio. The tentative program calls for sectional meetings on divisions of the industry such as metals, foundries, mines and quarries. J. M. Woltz, safety director of the Younstown Sheet & Tube Company, is chairman of the metal section. In connection with the conference there will be exhibits of posters, models of safety devices, etc.

Premier Record

What is designated as the premier safety first record was the "No Lost Time Accidents" for 125 days at the Joliet plant of the Illinois Steel Company. During this time 2,587 men worked.

Iron and Steel Industry Getting Results

Reviewing the accident situation in the metals industry, Dr. Lucian W. Chaney, of the U. S. Bureau of Labor Statistics, recently told the Sixteenth Annual Safety Congress delegates that the average experience revealed iron and steel accidents in 1926 showed a further decline in frequency, but a slight rise in severity rates against 1925 when there was registered a slight decline in both frequency and severity rates.

"The iron and steel industry has accomplished noteworthy results in accident prevention," stated Dr. Chaney. "While the rate of progress has slowed down considerably, there is still possibility of further progress."

Course in Safety First

A course in the prevention of accidents will become a permanent part of the curriculum of New York University when that institution starts its classes on October 3, according to the announcement of Mr. Arthur Williams, president of the American Museum of Safety, which is co-operating with the university in presenting the course, given last year as an experiment and meeting with unbounded success.

A distinguished list of men who have had practical experience in accident prevention work will act as instructors in the classes during the course. The director will be C. W. Price, outstanding as a consulting safety engineer of New York City and formerly general manager of the National Safety Council.

Red Cross Roll Call

The entire Metals and Machinery Field in New York City will be intensively covered in the 1927 Red Cross Roll Call, according to the plan of representative leaders who, as volunteer chairmen of specially organized groups, are already formulating a comprehensive Roll Call program.

The chairmen of the groups covering the Metals and Machinery field anticipate generous support for the forthcoming appeal and aim at a unanimous enrollment of the personnel throughout their field.

OCT 20 1927

The Blast Furnace and Steel Plant

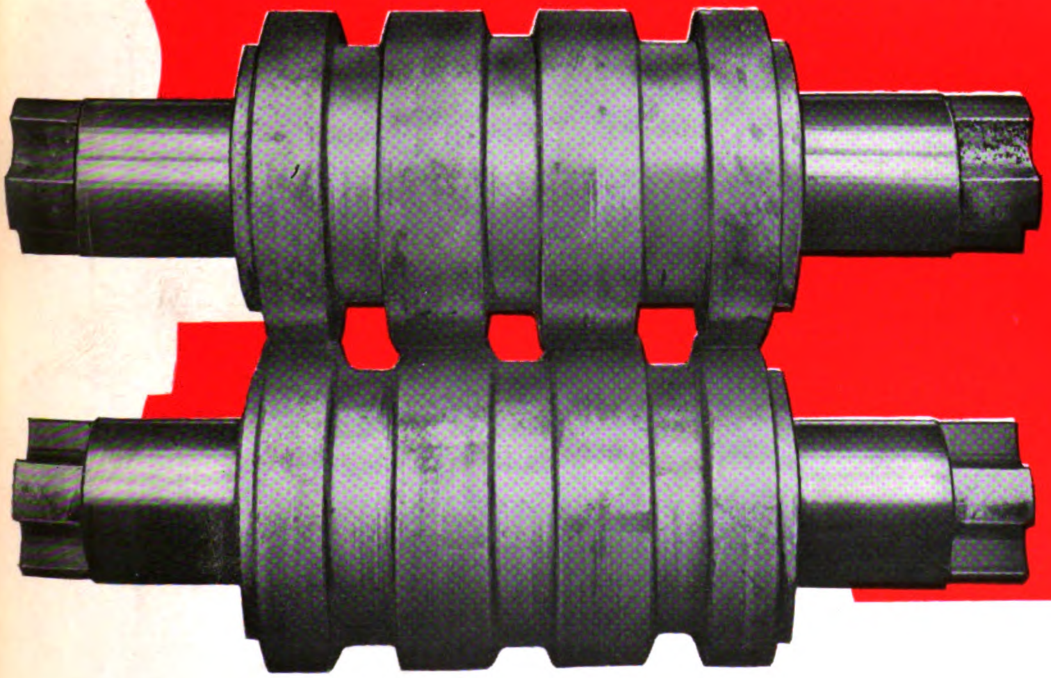
Member of the Audit Bureau of Circulations

PITTSBURGH, PA., OCTOBER, 1927

Entered as second class mail matter at Pittsburgh, Pa., under the act of Congress, March 3, 1879.

East Engin. Library

"Wheeling Quality" ROLLS



Wheeling Mold & Foundry Co.
Wheeling, West Virginia